Air & Space

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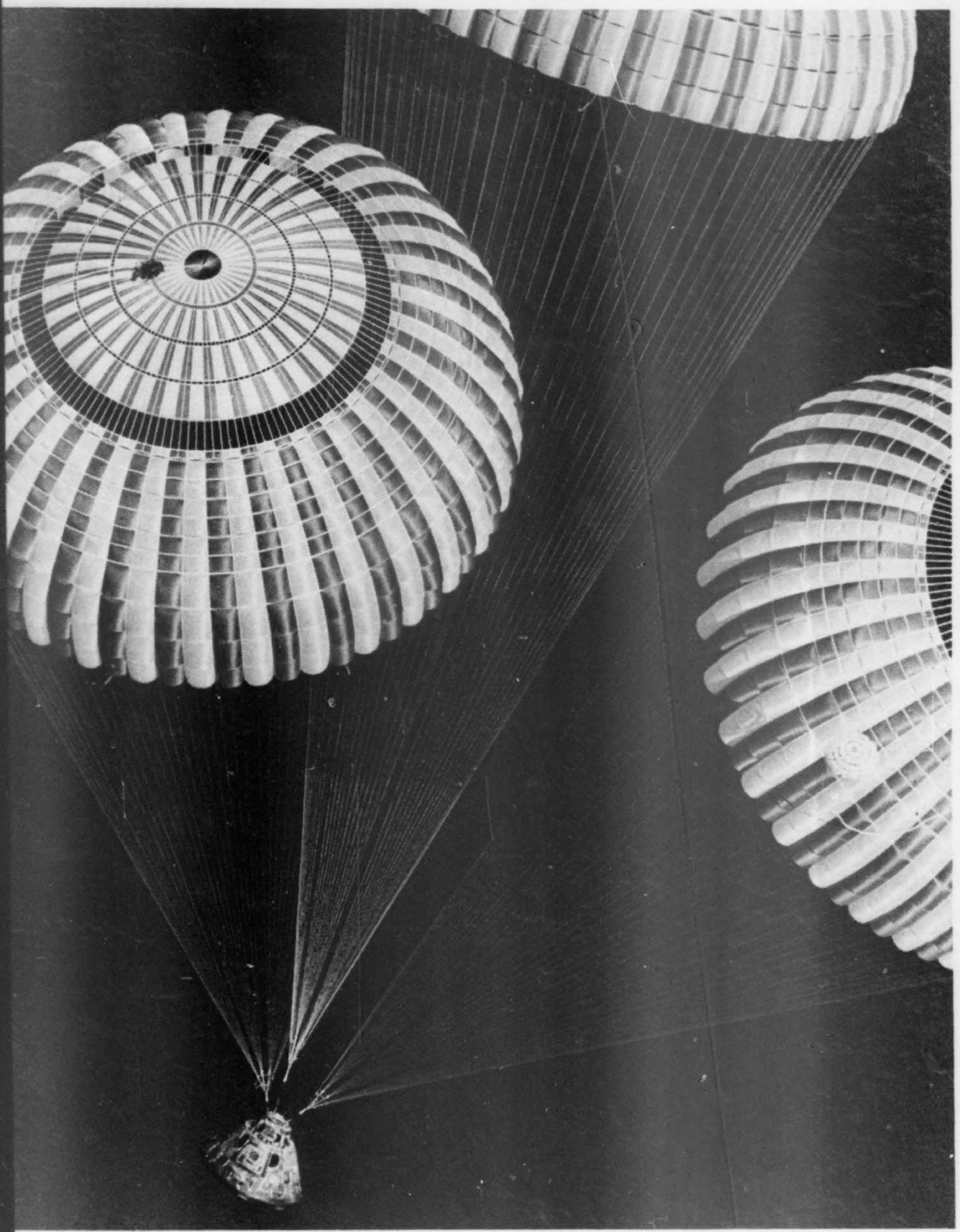

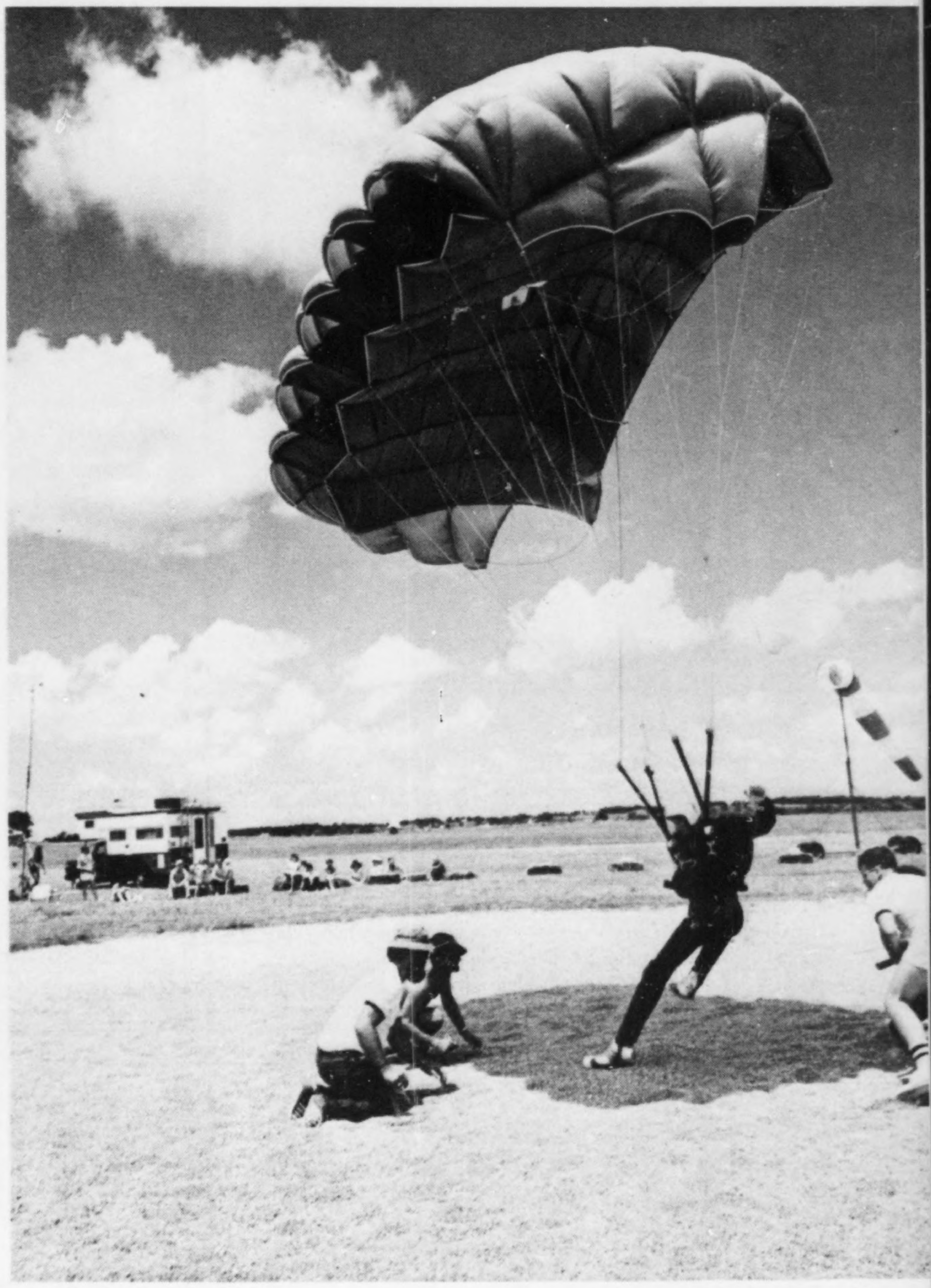

PARACHUTES

On December 19, 1972, astronauts Eugene A. Cernan, Ronald E. Evans, and Harrison H. Schmitt came hurtling back to Earth in the Apollo 17 Command Module. They had traveled 800,000 kilometers (500,000 miles) through the emptiness of space, had walked and driven upon the Moon. Whether their lunar landing mission would end in triumph or tragedy now depended on three tightly packed bundles of cloth—the Command Module's parachutes.

All three Apollo 17 parachutes worked as designed (above left), and the astronauts splashed down safely in the Pacific Ocean.

The parachute—originally conceived for descents centuries before successful human flight—has been developed into a highly reliable mechanical device in recent decades. Like the crew of Apollo 17, all previous U.S. astronauts and test animals that rode wingless rockets into space returned safely to Earth by parachute.

Today, thousands of skydivers in pursuit of sport and recreation stake their lives on the high reliability of modern parachute equipment. Above right, a competitor at the 1976 U.S. Parachuting Championships stomps a 10-centimeter (4-inch) disc in accuracy competition.

The jumper's double-surfaced "ram-air" or "square" parachute canopy creates aerodynamic lift like an airplane wing. The canopy scoops air with its open leading edge to pressurize and maintain its airfoil shape. That shape makes possible highly maneuverable flight—speeds up to 32-48 kilometers (20-30 miles) per hour, gliding more than 3 meters forward for every meter of descent, and braking to stand-up landings on one foot. More on parachutes, page 4.

SCAN

For brevity, the National Air and Space Museum is often referred to in these pages as NASM. The National Aeronautics and Space Administration is NASA.

Air & Space, a mini-magazine for educators, is published every other month, September through May, as an outreach of the National Air and Space Museum, Smithsonian Institution, Washington, DC.

Air & Space combines information from many sources for a condensed overview of the history, science, technology, and social impact of selected aviation and space subjects.

MUSEUM HOURS

Until Labor Day (September 1), the Museum will be open from 10 a.m. to 9 p.m.; starting September 2, Museum hours will be 10 a.m. to 5:30 p.m. The Museum is open to the public every day of the year except Christmas.

SPECIAL PRESENTATIONS CALENDAR

The NASM Special Presentations Calendar is issued quarterly and is available without charge to the general public. To be put on the mailing list, send your name and address to Quarterly Calendar, Presentations Division, National Air and Space Museum, Washington, DC 20560.

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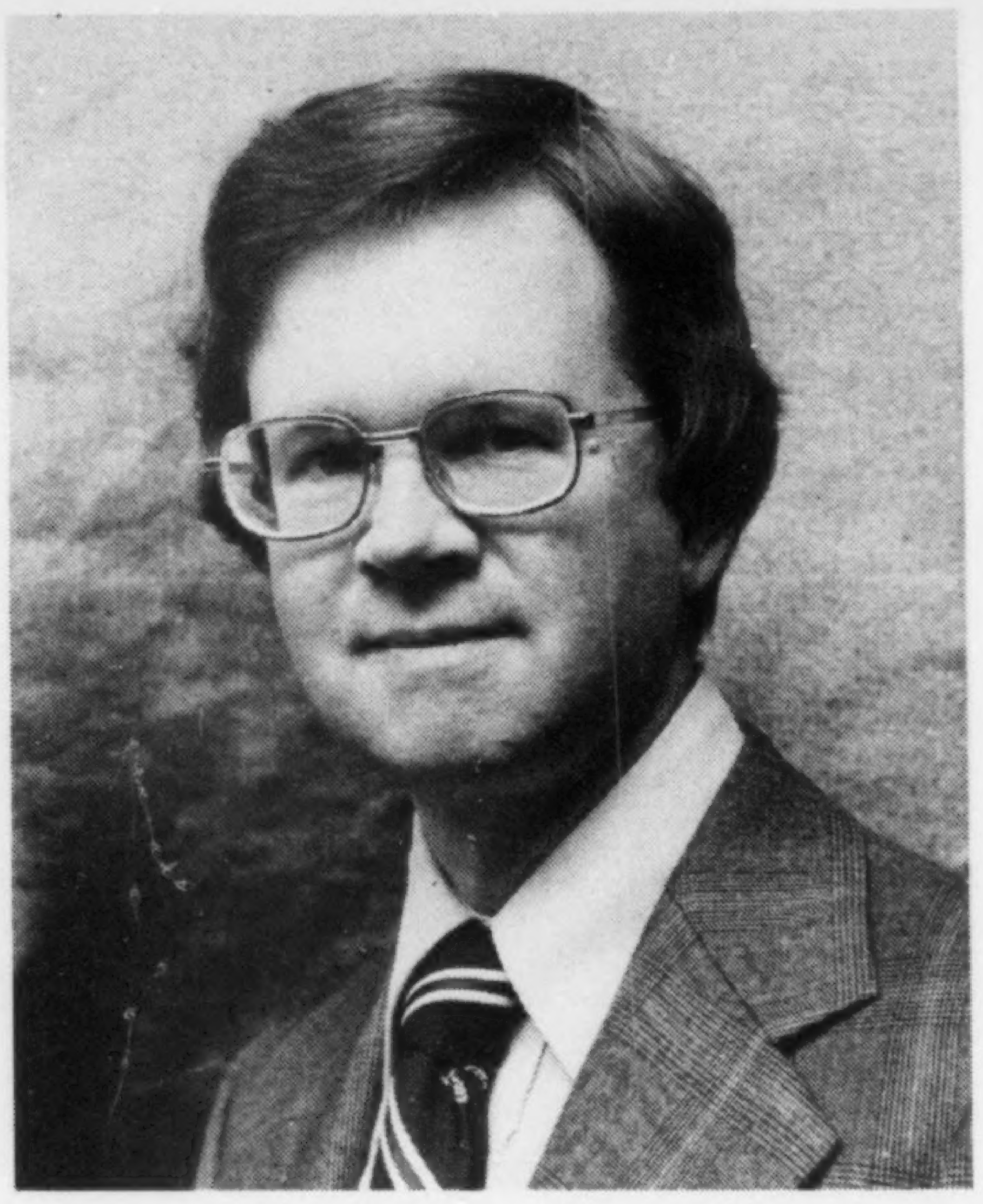
Briefing

Noel W. Hinners
Director, NASM



One of the earliest fears detectable in babies is that of falling. As we grow up, we try to protect ourselves against the dangers of falling, either by avoiding situations that threaten to make us fall, or by easing the effect of a fall. Having accomplished that, we then seem to get a special thrill out of testing ourselves against those fears, even to the point at times of flirting with death. Since most of us have no particular desire to exceed the bounds of survival—it is exceedingly more pleasant to approach the limit and survive in sufficient health to brag about the accomplishment—we frequently call on mechanical aids to give us a desirable margin of safety. Thus some 500 years ago did an "engineer" design the first known "guard" against a "fall" (possibly the fall awaiting those who leaped in desperation from burning buildings). If you were a linguist of the day, you could combine the equivalent Latin *parare* (to guard against) with the French *chute* (a fall) and coin the word *parachute*.

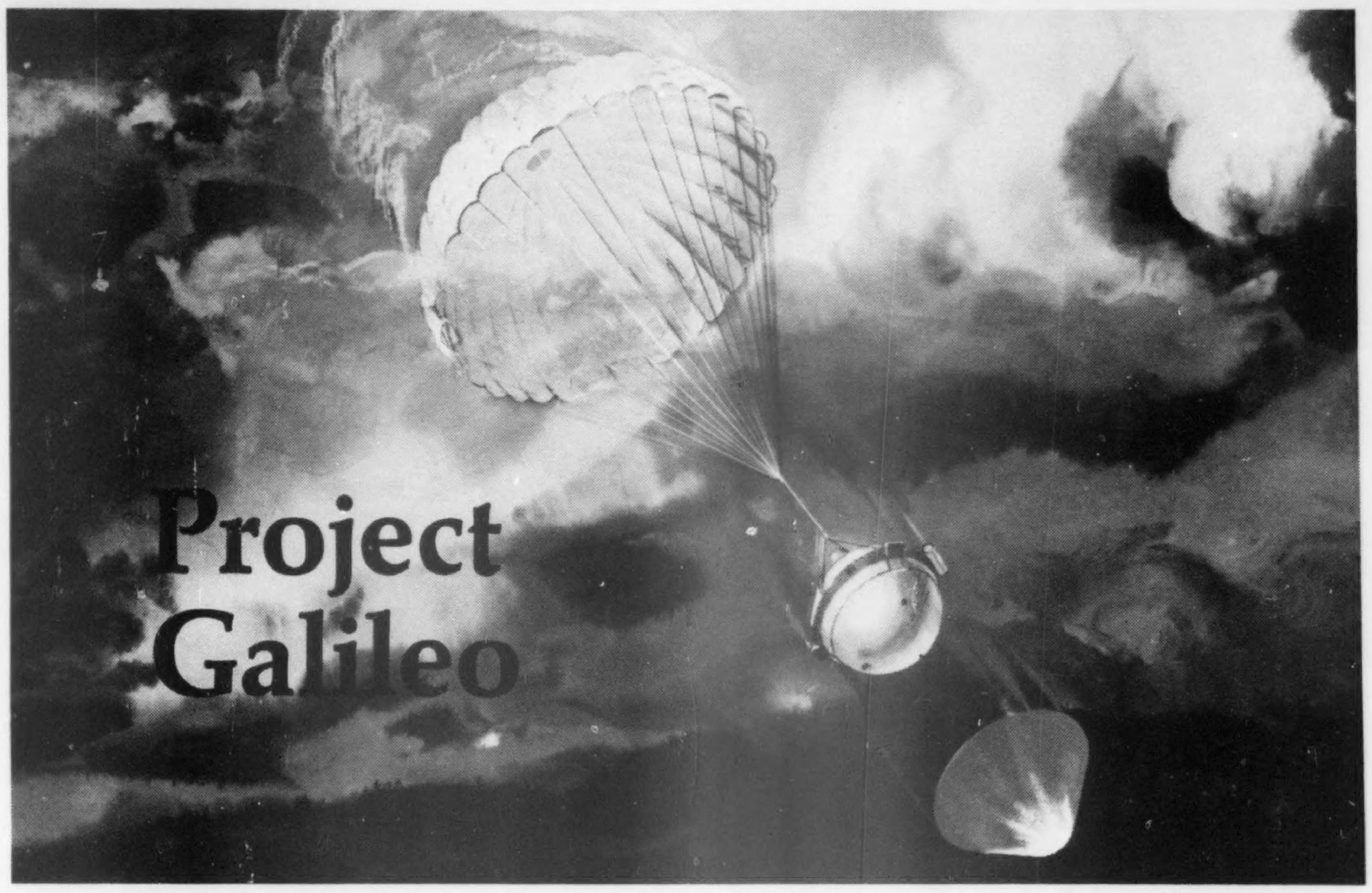
Today, the parachute—the theme of this issue of *Air & Space*—serves not only to rescue people from aerial emergencies (as it has for over 200,000 persons to date). It also enables aerial adventurers to experience the thrill of extended freefall (skydiving), live to tell about it, and do it again!

We've come a long way in the past seven decades in the use of parachutes. Used sparingly in World War I, they were greatly improved during the 1920s and '30s. Parachutes were used extensively in World War II for both escape from damaged airplanes and the rapid delivery of men and supplies to the battlefield. During the postwar period, with the advent of high-speed aircraft, the parachute became indispensable for both slowing them down during landing and aiding their recovery from spins.

A relatively new use of the parachute during the past 20 years has been in the space program, most obviously in aiding the safe descent of the U.S. and Soviet manned spacecraft returning from Earth orbit. In fact, without parachutes, many of the space missions might not have been possible, because building shock-absorbing material into the spacecraft for landing would have added more weight than was allowable. In space science programs, the parachute has served an equally important function, that of slowing down planetary probes to enable soft landings (on Mars by the Viking Lander) or to give them enough time to measure the structure and composition of the planet under study (Pioneer Venus and the Jupiter probe on the Galileo mission).

Finally, as you read this issue of *Air & Space*, don't forget to look at the parachute as a work of art. There are few sights prettier than a big, billowing conical parachute descending, or the graceful, controlled glides of the bright multi-colored rectangular and triangular sport canopies that skydivers fly to tiptoe touchdowns within centimeters of a preselected target.

Project Galileo



Above: Streaking into the turbulent upper layers of Jupiter's primitive atmosphere, the Galileo Probe will simultaneously deploy its main parachute and jettison the heat shield that will protect the descent module during atmospheric entry. NASA-sponsored Project Galileo will be a two-part unmanned scientific mission to our Solar System's largest planet: the Probe will study the Jovian atmosphere, while the Orbiter will make detailed observations of Jupiter, its satellites, and magnetosphere.

More than 375 years after Galileo Galilei looked through his telescope in 1610 and discovered Jupiter's four largest satellites (moons), Project Galileo—sponsored by NASA—will orbit a spacecraft around Jupiter and send a probe deep into that planet's atmosphere.

The purpose of the Galileo mission is to seek important information about the origin and evolution of the Solar System. Jupiter's primitive atmosphere is believed to be a sample of the original material from which stars are formed, still unmodified by nuclear processes. Therefore, scientists are confident that the Jovian system—Jupiter and its satellites—will reveal important new insights into large-scale phenomena that relate to our understanding of all of the Sun's planets, including Earth.

Project Galileo is designed to provide an in-depth study of Jupiter, its four largest (Galilean) satellites, and its magnetosphere (the space around Jupiter occupied by its strong magnetic field). To conduct all these observations, two kinds of spacecraft are required: a probe and an orbiter.

The successful Voyager missions to Jupiter and its satellites in 1979 provided planetary scientists with a wealth of new information about this complicated system. The Voyager results emphasized the need for the unique capabilities that a probe and an orbiter could bring together to Jovian scientific investigations.

Voyager returned fascinating pictures of the motions of the clouds in Jupiter's atmosphere; however, the data suggest that the sources of these complex meteorological movements lie deep within the atmosphere. The Galileo Probe will extend our knowledge in depth, making direct measurements of the composition, energy balance, and structure of Jupiter's atmosphere. The Probe will penetrate at least 100 kilometers (62 miles) below the visible cloud layer before it loses contact with Earth. The Probe will reach a pressure of 10 to 20 Earth atmospheres.

The Orbiter will extend our knowledge in time by following the motions of Jovian clouds during the 20 or more months in which it will return data from orbit about Jupiter. The Orbiter's improved instrumentation and close satellite flybys (10 to 100 times closer than those of Voyager) will allow much more detailed studies of the four diverse Galilean satellites. Several encounters with each satellite will give high-resolution information on the structure and composition of different areas of the surfaces. The multiple close encounters also will permit probing the gravity and the possible magnetic fields of the satellites, thus providing clues to their internal structures.

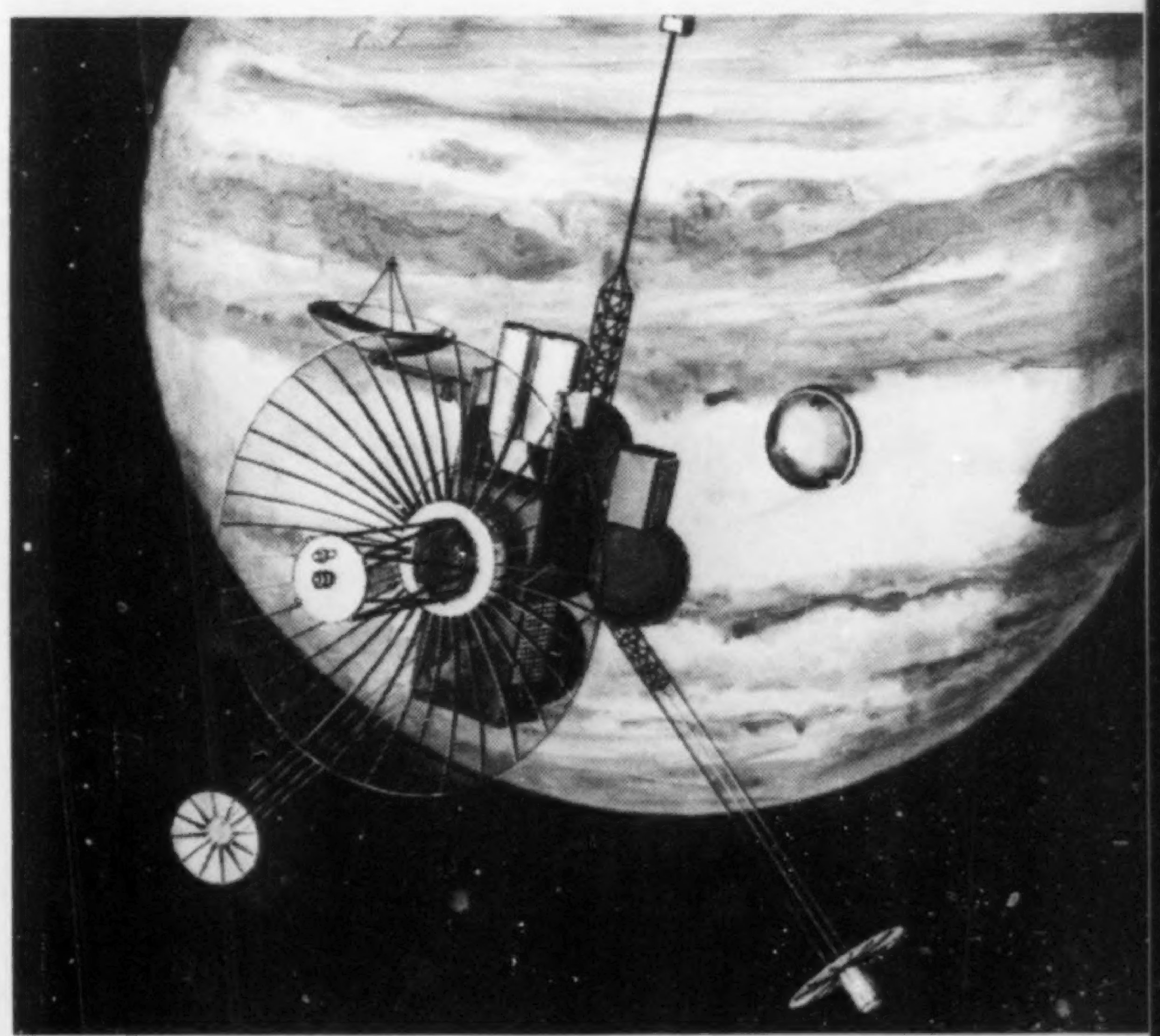
Voyager provided abundant evidence for many phenomena in the Jovian system that change over time, phenomena that it found in 1979 to be changed in many important respects since Pioneer 10 and 11 flew by in 1973 and 1974. The whole range of Orbiter investigations—both remote sensing of the planet and its satellites, and direct measurement of ionized particles and magnetic fields in the magnetosphere—will be required to unravel some of the major Jovian mysteries. These include the complex interactions among volcanic gases from Io (Jupiter's most geologically active satellite), the composition and energy balance of charged particles in the magnetosphere, and the state of Jupiter's upper atmosphere and aurorae.

Both Probe and Orbiter experiments will allow scientists to follow up on Voyager's discoveries, such as lightning on Jupiter, the planet's ring system, and the volcanic activity on Io.

The Project Galileo spacecraft was designed to be carried to Low Earth Orbit by the Space Transportation System (Shuttle Orbiter) and launched after separation from the Shuttle. NASA originally planned to launch Galileo in early 1982. The 1982 launch plan, offering favorable planetary positions for reaching Jupiter via a Mars gravity assist, presented an attractive opportunity to combine both spacecraft in a single, cost-effective launch. (The Probe and Orbiter would separate shortly before reaching Jupiter.)

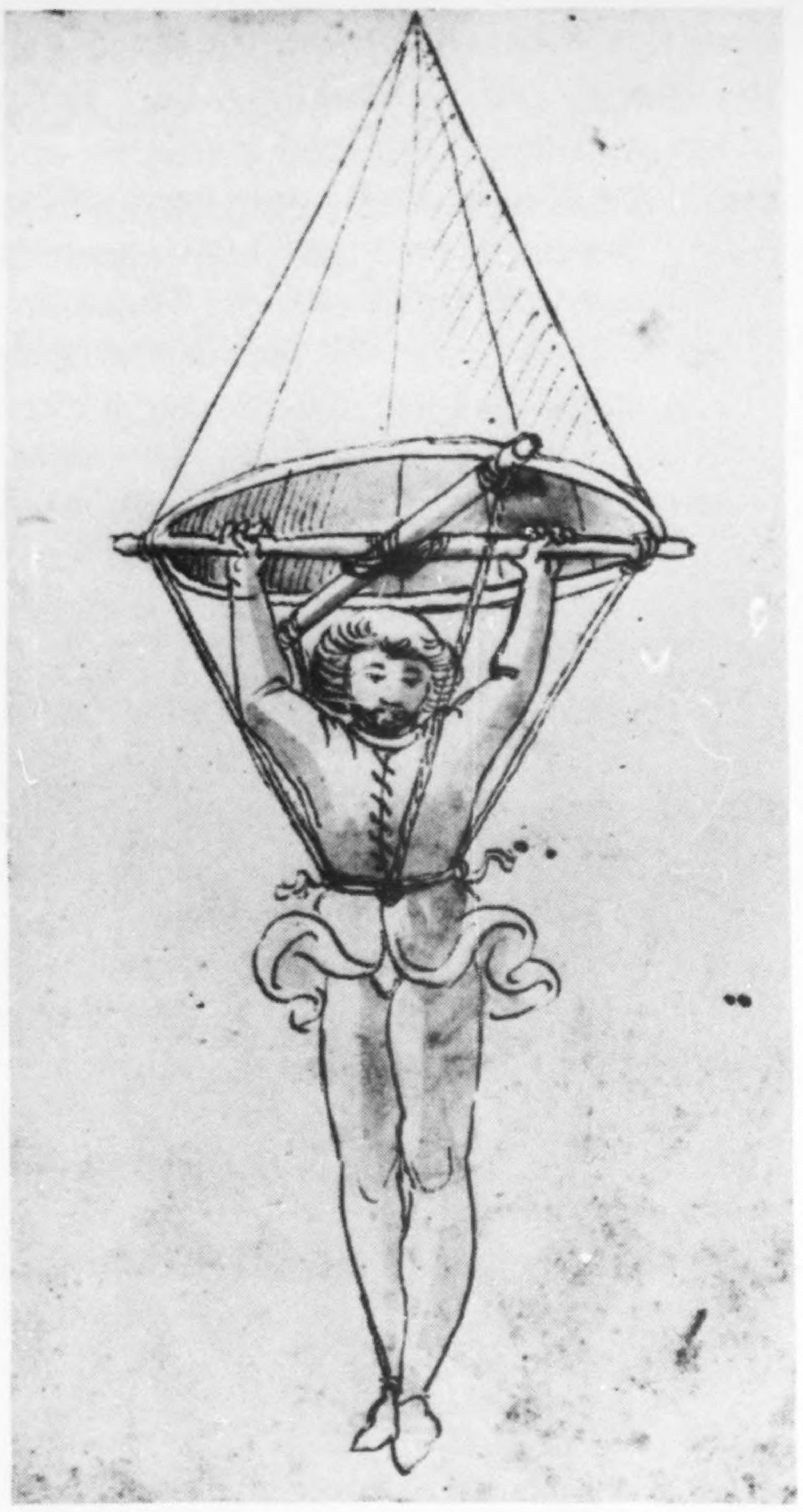
However, delays in the Space Transportation System schedule (see pages 8-9) have made it highly unlikely that this combined mission could be launched in 1982. Nevertheless, the basic Project Galileo objectives will still be achieved through separate launches of the Probe and Orbiter (similar to the recent Pioneer Venus strategy). This will be done by launching the Orbiter in early 1984, when Mars is again available (although not in as favorable a position) to provide a gravity assist. The Probe—attached to the Probe Carrier, a new spacecraft designed to relay radio signals from the Probe back to Earth—will then be launched a few weeks later. Arrival of the Probe will be scheduled so that the Orbiter may view and characterize the Probe entry.

Right: Designed for a single launch in 1982, the original Project Galileo concept involved sending the Orbiter and Probe to Jupiter as a unit. Nearing Jupiter, the two instrument packages would separate, as shown in this artist's rendering. NASA's revised plans call for two separate launches in 1984.



PARACHUTES

have been letting their precious cargoes down—gently—for more than 180 years



Above: This parachute design, probably the world's first, is from a sketchbook of the late 1470s or early 1480s by an unnamed engineer from Sienna, Italy.

by C. G. Sweeting
Curator of Flight Materiel
Department of Aeronautics, NASM

Although the exact origin of the parachute is not known, the basic concept goes back several centuries. The parasol, in use in Assyria 2800 years ago, is believed to have been the inspiration for the parachute because of the resistance it offered to the wind. Early legends in China and elsewhere mention experiments with umbrellas and similar devices. What may have been the world's first actual parachute design was a conical contraption drawn by an unnamed engineer—probably from Sienna, Italy—in the late 1470s or early 1480s. Leonardo da Vinci sketched a pyramid-shaped parachute in 1495 and described its proposed use: escape from tall burning buildings. Hungarian bishop Faustus Verantius published an illustration of a parachute—a square wooden framework covered with fabric—in his book *New Machines,* printed in 1615-16. There is no proof that any of these designs were ever tested.

With the invention of the balloon in the early 1780s (see "The Invention of Lighter-than-Air Craft," May-June 1979 *Air & Space*), the parachute found a practical application. Exhibition parachuting spread across Europe despite the unstable nature of early parachute canopies.

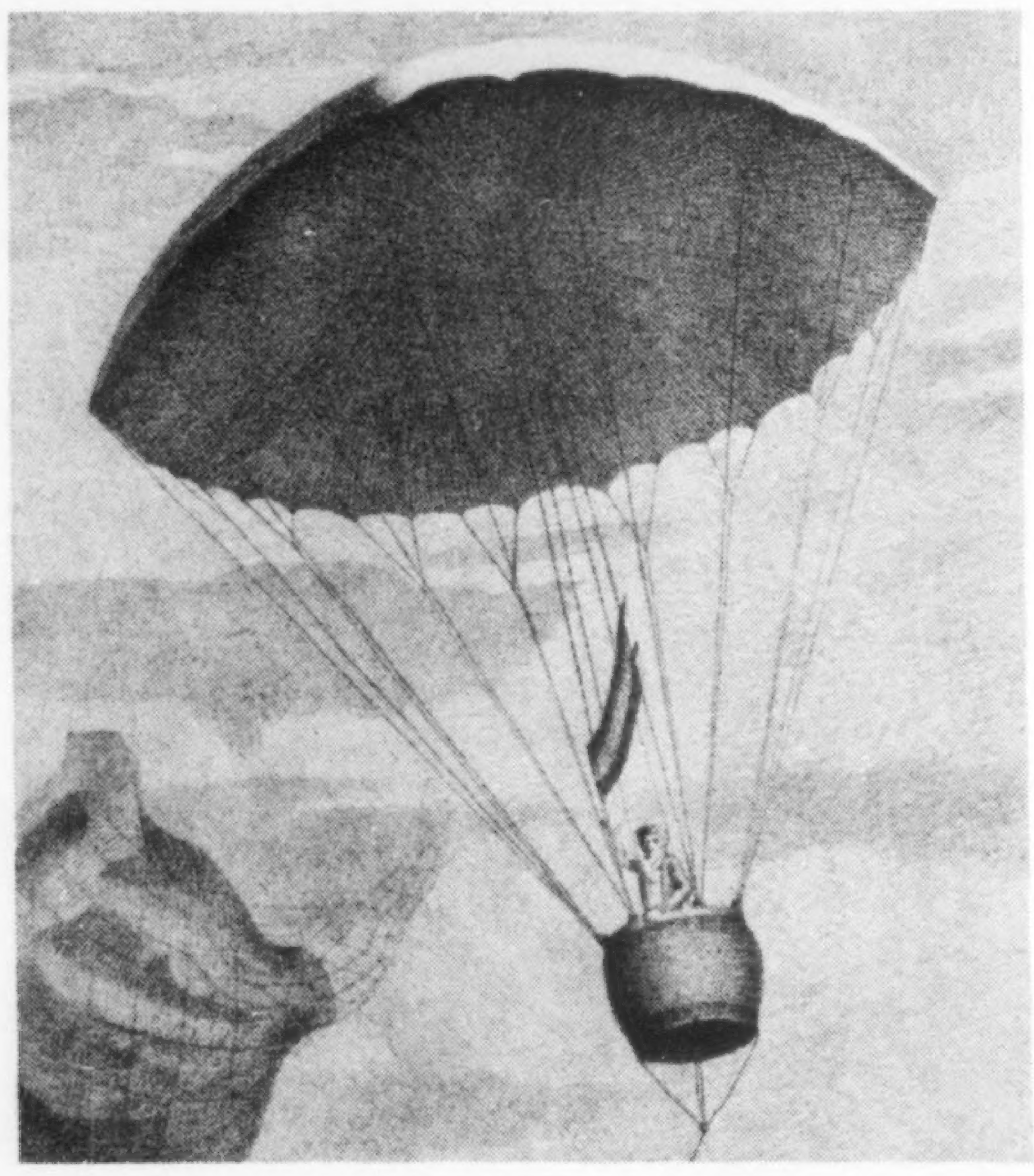
André-Jacques Garnerin, a Frenchman, is credited with making the first parachute descent from a balloon on October 22, 1797, from a height of about 640 meters (2100 feet) above Paris. Garnerin rode in a wicker basket hung from his umbrella-shaped parachute. Louis Charlies Guille made the first parachute descent in the New World in 1819 when he cut away from a balloon flying 152 meters (499 feet) over Jersey City, N.J. Many thrilling exhibition descents were made from balloons during the 1800s, but the typical parachute was still a bulky, inefficient, stiff-ribbed umbrella that was impractical as an emergency lifesaving device.

The Parachute and the Airplane

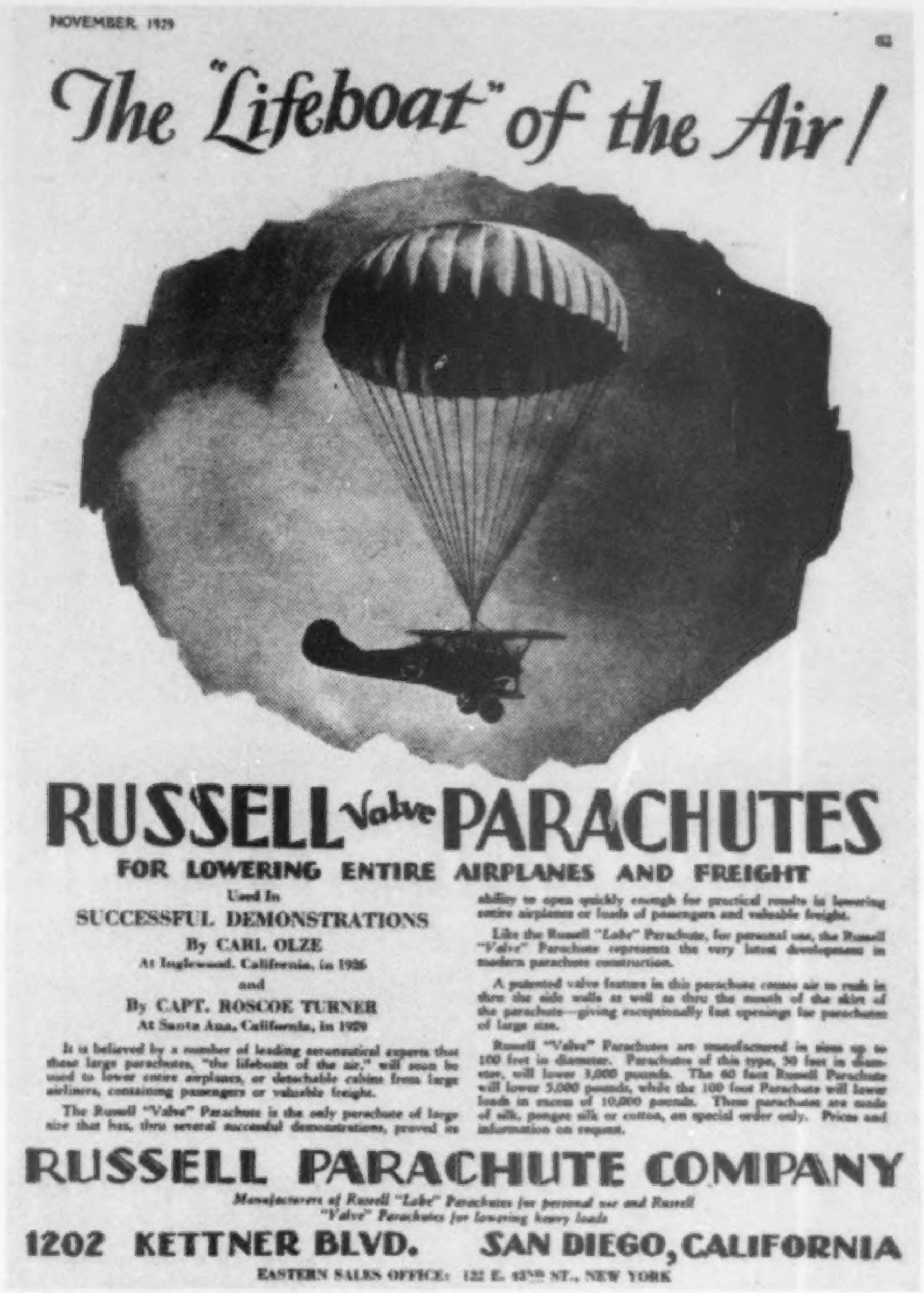
Few early airplane pilots used parachutes. Despite many engine and structural failures, most of the pioneer aviators preferred to take their chances with the disabled aircraft. Many pilots considered parachutes to be unreliable or suitable only for exhibition drops.

To be practical for use with an airplane, a parachute had to be relatively lightweight, compact, strong and, preferably, opened by the jumper after he cleared the aircraft. (Many early parachutes were opened by a static line, a strong cord connecting the parachute pack with the airplane. The static line opened the pack as the jumper fell away from the aircraft.)

Charles Broadwick, a balloonist and jumper, developed a compact parachute that he wore on his body and used hundreds of times for exhibitions. Leo Stevens also developed a para-



Above: André-Jacques Garnerin made the first parachute descent from a balloon that he released over Paris on October 22, 1797. Right: Attack by enemy airplanes motivated World War I aerial observers to leap from their tethered balloons. Note the parachute suspension lines pulling the parachute canopy from the container attached to the balloon's rigging. Below: The U.S. Army Type A parachute introduced in 1919 was one of the first that could be worn on the body. Wearing the black hat is Leslie L. "Sky-Hi" Irvin, parachute inventor, jumper, and manufacturer.



NOVEMBER, 1929

The "Lifeboat" of the Air!

RUSSELL *Valve* PARACHUTES

FOR LOWERING ENTIRE AIRPLANES AND FREIGHT

Used In
SUCCESSFUL DEMONSTRATIONS
By CARL OLZE
At Inglewood, California, in 1926
and
By CAPT. ROSCOE TURNER
At Santa Ana, California, in 1929

It is believed by a number of leading aeronautical experts that these large parachutes, "the lifeboats of the air," will soon be used to lower entire airplanes, or detachable cabins from large airliners, containing passengers or valuable freight.

The Russell "Valve" Parachute is the only parachute of large size that has, thru several successful demonstrations, proved its ability to open quickly enough for practical results in lowering entire airplanes or loads of passengers and valuable freight.

Like the Russell "Lobe" Parachute, for personal use, the Russell "Valve" Parachute represents the very latest development in modern parachute construction.

A patented valve feature in this parachute causes air to rush in thru the side walls as well as thru the mouth of the skirt of the parachute—giving exceptionally fast openings for parachutes of large size.

Russell "Valve" Parachutes are manufactured in sizes up to 100 feet in diameter. Parachutes of this type, 30 feet in diameter, will lower 3,000 pounds. The 60 foot Russell Parachute will lower 5,000 pounds, while the 100 foot Parachute will lower loads in excess of 10,000 pounds. These parachutes are made of silk, pongee silk or cotton, on special order only. Prices and information on request.

RUSSELL PARACHUTE COMPANY

Manufacturers of Russell "Lobe" Parachutes for personal use and Russell "Valve" Parachutes for lowering heavy loads

1202 KETTNER BLVD. SAN DIEGO, CALIFORNIA

EASTERN SALES OFFICE: 122 E. 42ND ST., NEW YORK

Inventors have experimented for decades with large parachutes designed to lower entire airplanes or detachable aircraft cabins to safety. Above: A November 1929 Russell Parachute Company advertisement described its "Valve" parachute as "The 'Lifeboat' of the Air."

chute pack carried on the person, and is credited with inventing the ripcord.

The first "official" parachute jump from an airplane flying at full speed was made on March 1, 1912, when Capt. Albert Berry jumped from a Benoist biplane over Jefferson Barracks, Mo. Capt. Berry was not an Army aviator, but a civilian professional parachutist. (Early aeronauts and balloon jumpers often used the title "Captain.")

The Parachute in World War I

During World War I, the parachute was used successfully by military aeronauts on both sides who were forced to leap from the baskets of tethered observation balloons attacked by enemy aircraft. Despite improvements in parachutes, few were used by Allied airplane pilots during the War. By 1918, German aviators began using a static line parachute, designed by Otto Heinecke, that was carried on the airplane. Many Germans—including the famous ace Ernst Udet, who bailed out of his Fokker in the summer of 1918—saved their lives with this parachute.

Allied pilots began demanding parachutes, too. Development of a parachute compact enough to be carried aboard small pursuit airplanes began in earnest.

The Parachute Comes of Age

In 1918, experiments were begun at the U.S. Army's McCook Field near Dayton, Ohio, to perfect a true freefall parachute that could be worn on the body. Floyd Smith and Guy Ball, parachute pioneers, are credited with developing the Army Type A parachute, which was a great improvement over all previous types. The simplified Army Type S that followed the Type A was the basis for all modern personnel parachutes. Parachute containers became available in three basic types—back, seat, and lap pack—with the detachable chest pack coming later.

World War II saw the first use of parachutes to swiftly deploy large numbers of soldiers and equipment. Both Axis and Allied paratroopers figured prominently in several key campaigns. Inset above: Heavily laden U.S. Army paratroopers, their faces blackened for combat, 'chute up for the invasion of Normandy in June 1944. Above: Parachutes and airborne troops cover a drop zone as an entire battalion of the U.S. Army's 82nd Airborne Division simulates an aerial assault during the 1950s.

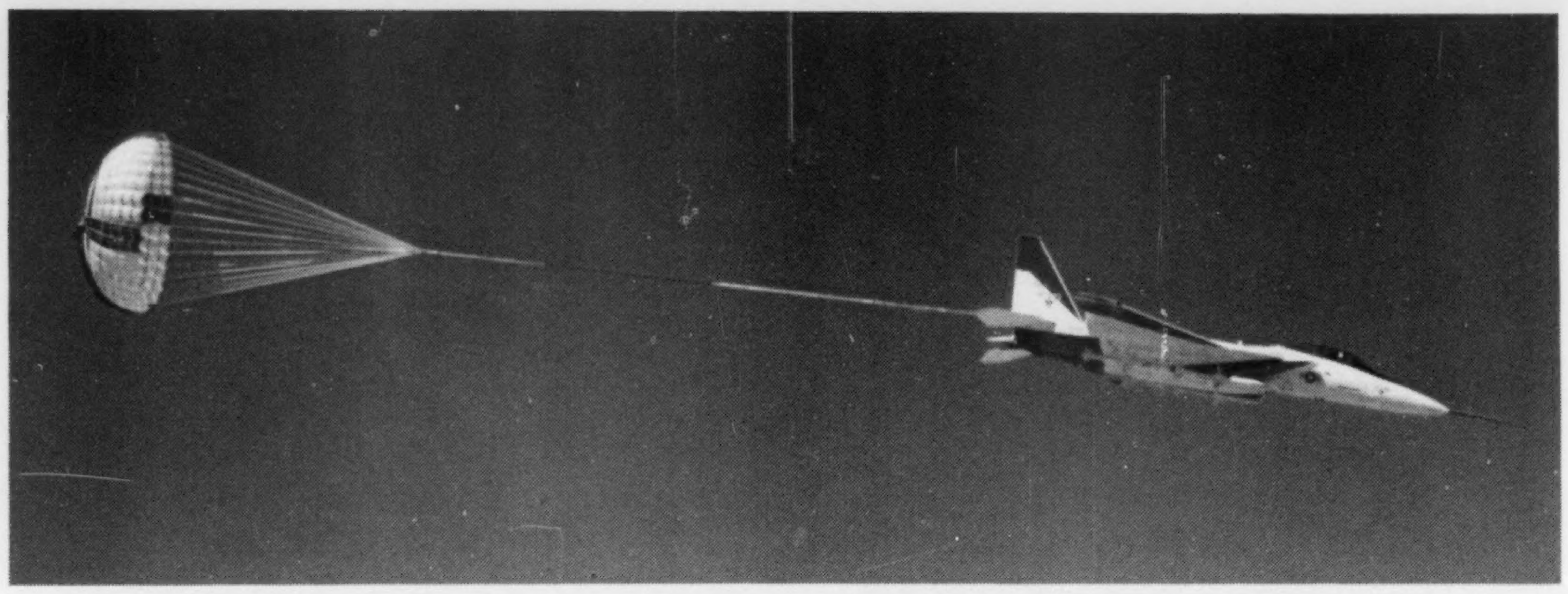
Lt. Harold R. Harris is credited with making the first military emergency parachute jump from an airplane in the United States over McCook Field on October 20, 1922. Shortly thereafter, a club was founded at McCook Field with membership limited to airmen who had made successful emergency parachute jumps. This group eventually evolved into the Caterpillar Club, administered by the Irving Air Chute Company. Leslie Irvin, founder of the company, chose the silkworm caterpillar for the Club's namesake, as many of the parachutes of the time were made of silk. (Today, virtually all parachutes are made of nylon.) Since then, thousands of people have proudly worn the Caterpillar Club lapel pin, showing that their lives have been saved by a parachute.

Several interesting types of parachutes were developed during the 1920s and '30s. The Russell "Lobe" type was extremely stable and reduced swaying. The "Triangle," invented by Major E. L. Hoffman, director of Army parachute development at McCook Field, was not only stable, but steerable, and had a forward speed of about 5-8 kilometers (3-5 miles) per hour. It was the first real steerable parachute design and was greatly favored by exhibition jumpers.

The Parachute in World War II

During World War II, scientific methods and formal engineering techniques were used to design new types of parachutes in the United States, England, and Germany.

Parachutes saved thousands of airmen, lowered supplies and equipment



Above: A U.S. Air Force McDonnell-Douglas F-15 Eagle jet fighter deploys a tail-mounted parachute to aid in recovery from a spin. Below: Many high-speed jet aircraft, like the U.S. Air Force North American F-100 Super Sabre interceptor shown in this 1950s photo, use parachutes to shorten their landing rollout. Left: Advances in modern parachute technology triggered a new variety of sport parachuting called "canopy relative work," in which skydivers maneuver gliding parachutes relative to each other to make formations like this five-canopy stack.

U.S. AIR FORCE
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to ground troops, and were used extensively to drop flares. Thousands of deadly mines dropped by parachute sank many ships.

The Germans were the first to use paratroops during World War II, dropping them into Norway, the Low Countries, Greece, and Crete. Large-scale Allied airborne operations in Sicily, Normandy, and Northern Europe helped speed the end of World War II.

The Parachute Today

Parachutes have saved more than 200,000 lives. Today, however, several types of parachutes are used for various purposes other than lifesaving.

The National Weather Service uses small parachutes to lower radiosonde instruments that have been carried aloft by balloons. Parachutes slow racing cars and high-speed military and test aircraft on landing. Many modern combat aircraft carry a special parachute in their tail sections to assist the pilot in recovering from a spin.

The United States and the Soviet Union have used parachutes extensively in their space programs, principally for spacecraft recovery. A special parachute system employing a newly-developed "disc-gap" type canopy was used to lower the lander sections of two Viking spacecraft through the thin atmosphere of Mars in 1976 (see back cover).

The Soviet Union pioneered the use of parachute medical teams that are dropped into remote areas to provide emergency medical service. In the United States, smokejumpers—airborne firefighters—have been parachuting into remote forest and grass fire areas since 1940.

Skydiving

Skydiving, as present-day sport parachuting is called, combines the exhilaration of flight completely free of mechanical assistance with the capability to land on a predetermined spot from thousands of meters in the air. The development of safe, simple, reliable equipment allowed parachuting to become the popular sport it is today. Since the late 1950s, scores of thousands of adventurous athletes have taken up skydiving. National and international competitions have developed, and in 1962, James Arender won the first world championship for the United States.

Now, guided by the U.S. Parachute Association and similar national organizations in many foreign countries, the sport has grown tremendously. All over the world, men and women are approaching the age-old dream of human flight. They swoop through the sky at speeds up to 320 kilometers (200 miles) per hour, wearing small, efficient deceleration devices that scarcely resemble conventional parachutes, but which make possible pinpoint precision landings after more than a minute of freefall. The traditional round parachute canopies are rapidly being replaced by a variety of rectangular configurations called "squares," which create aerodynamic lift in a manner similar to an airplane wing.

Today, with more than 25,000 active skydivers, the United States is a world leader in the sport.

Parachute Technology

A parachute is basically a device for adding to the resistance of a body moving through the air.

Parachute operation involves three phases: deployment (canopy and line extension), inflation, and descent. Parachute inflation actually occurs from the top (crown) of the canopy to the bottom (skirt). As air rushes into the canopy, a ball of air is formed in the top. This ball spreads outward until the canopy is completely inflated. Everyone has felt the pull or drag of an open umbrella on a windy day. At a certain velocity, when the drag of the canopy equals the weight of the load, a "terminal velocity" is maintained.

Parachutes may be designed with a variety of features, depending on the intended use and other factors such as weight of the load, terminal velocity, and desired rate of opening.

Student Activity

Parachute engineers test parachutes for many things—for example, rate of descent, strength, opening reliability, glide angle, stability in air turbulence, degree of oscillation (how far the suspended payload swings from side to side), and the time and altitude required for the parachute to open.

The results of these tests usually depend on several variables, such as the canopy's shape and size, fabric porosity, line length, suspended weight, and atmospheric conditions (temperature, humidity, gustiness).

Some of these tests are easy to duplicate with small, simple parachutes made from household materials. Divide students into small groups, each group performing its own tests.

Test No. 1: Rate of Descent

Set up a procedure for dropping a parachute at least four times—preferably in calm air. Do each drop exactly the same way, from the same height, at the same place. Measure the distance the parachute descends. Make a copy of the graphs shown on this page. On the Descent Times graph, record the duration of each parachute descent. Calculate the rate of descent in meters per second (meters of descent divided by duration of descent) for each drop. Record the results on the Rate of Descent graph. Compare results with those of other groups.

Example

A parachute made from a square of facial tissue lowers a single paper clip a distance of 1.8 meters in 4 seconds.

Rate of descent V

$$= \frac{\text{distance dropped}}{\text{time to drop}}$$

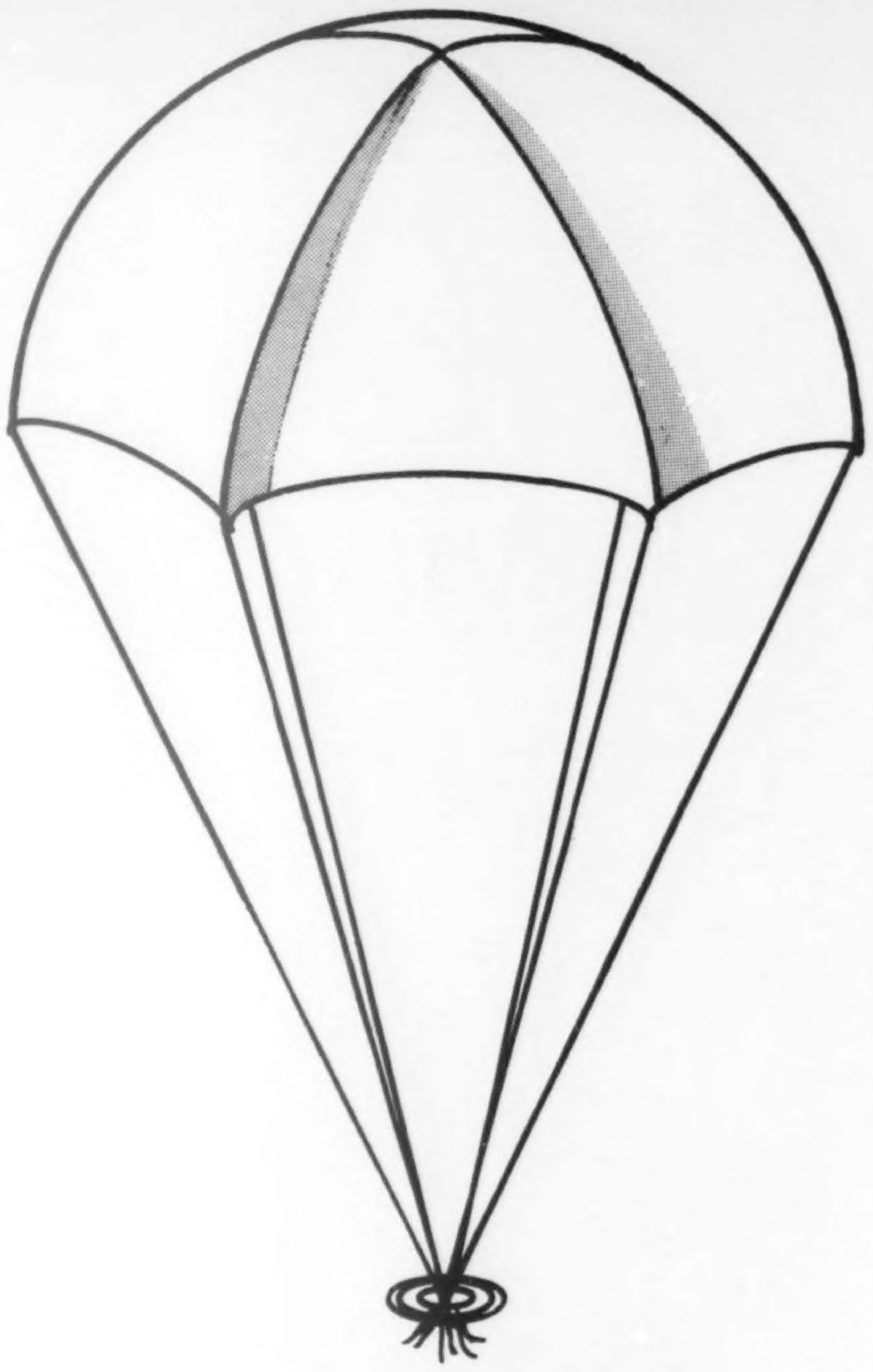
$$= \frac{1.8 \text{ meters}}{4 \text{ seconds}}$$

$$= .45 \text{ meters/second}$$

What kind of variables do you think determine the rate of descent? What is the importance of averaging the recorded times?

Test No. 2: Porosity vs. Rate of Descent

Conduct a second parachute drop experiment using parachutes made from different materials—for example, old sheets or pillowcases, plastic dry cleaner bags, reinforced tissue paper, nylon, and silk. Make each parachute the same size and shape as the others. Drop each parachute at least four times. Calculate the rate of descent for each canopy. Record the data on copies of the graphs; compare results.



Test No. 3: Payload Weight vs. Rate of Descent

Try different weights as the payload for the same parachute canopy. Record the descent times for each payload when parachuted from the same height. Calculate the rate of descent for each payload and graph the results.

Test No. 4: Canopy Shape vs. Rate of Descent

Ask students to calculate the dimensions of different canopies with the same area but different shapes (for example, a regular pentagon, square, equilateral triangle, and circle). Repeat the drop tests with each canopy (using the same weight, dropped from the same height) and calculate the rate of descent for each. Record and graph the results.

Making a Parachute

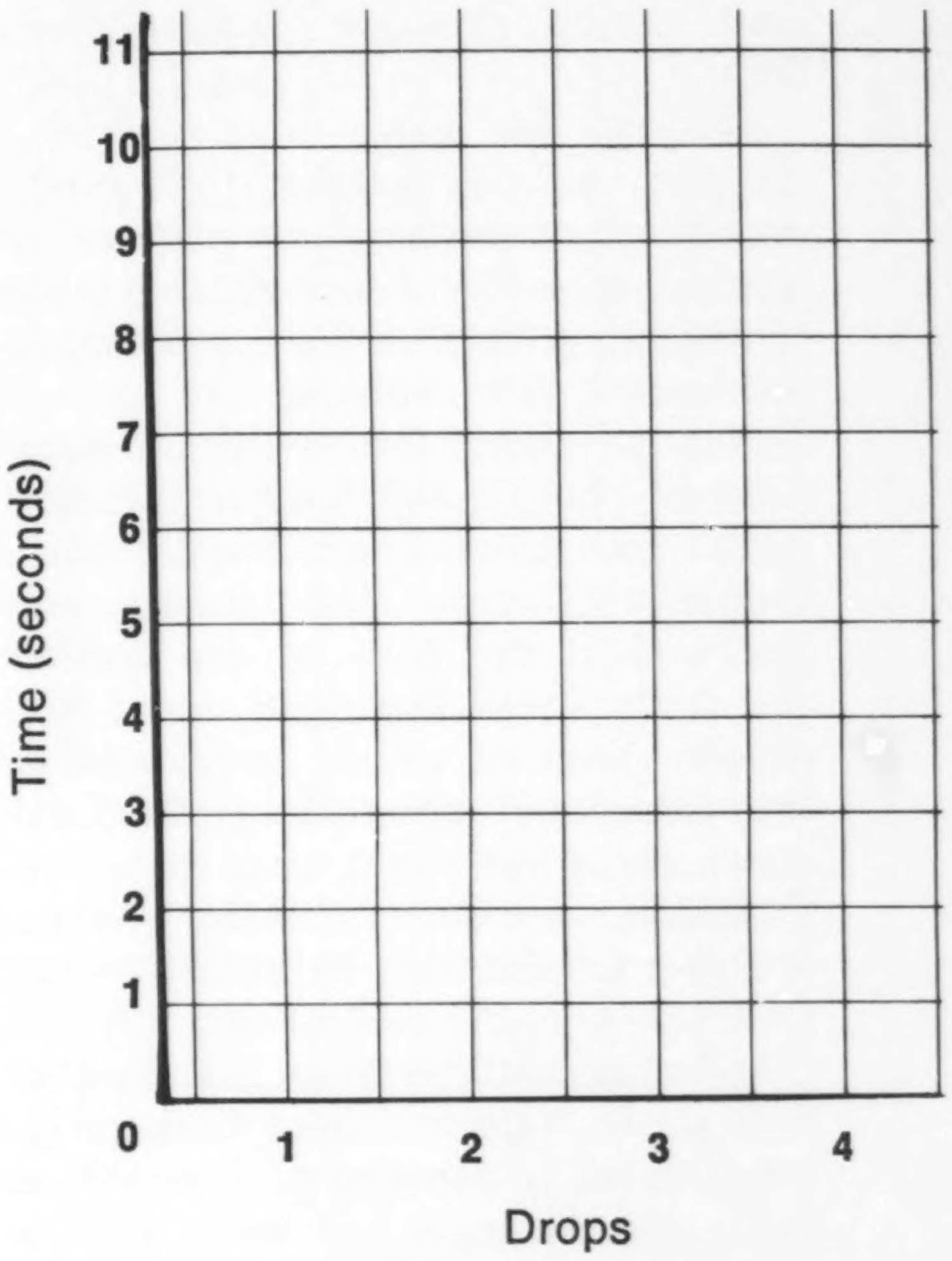
Furnish each group with a sheet of film plastic. (Dry-cleaning bags slit down one side work well.)

Instruct students to make a six-sided parachute canopy by cutting the plastic into a regular hexagon. Students should carefully cut hexagons with scissors or a modeling knife.

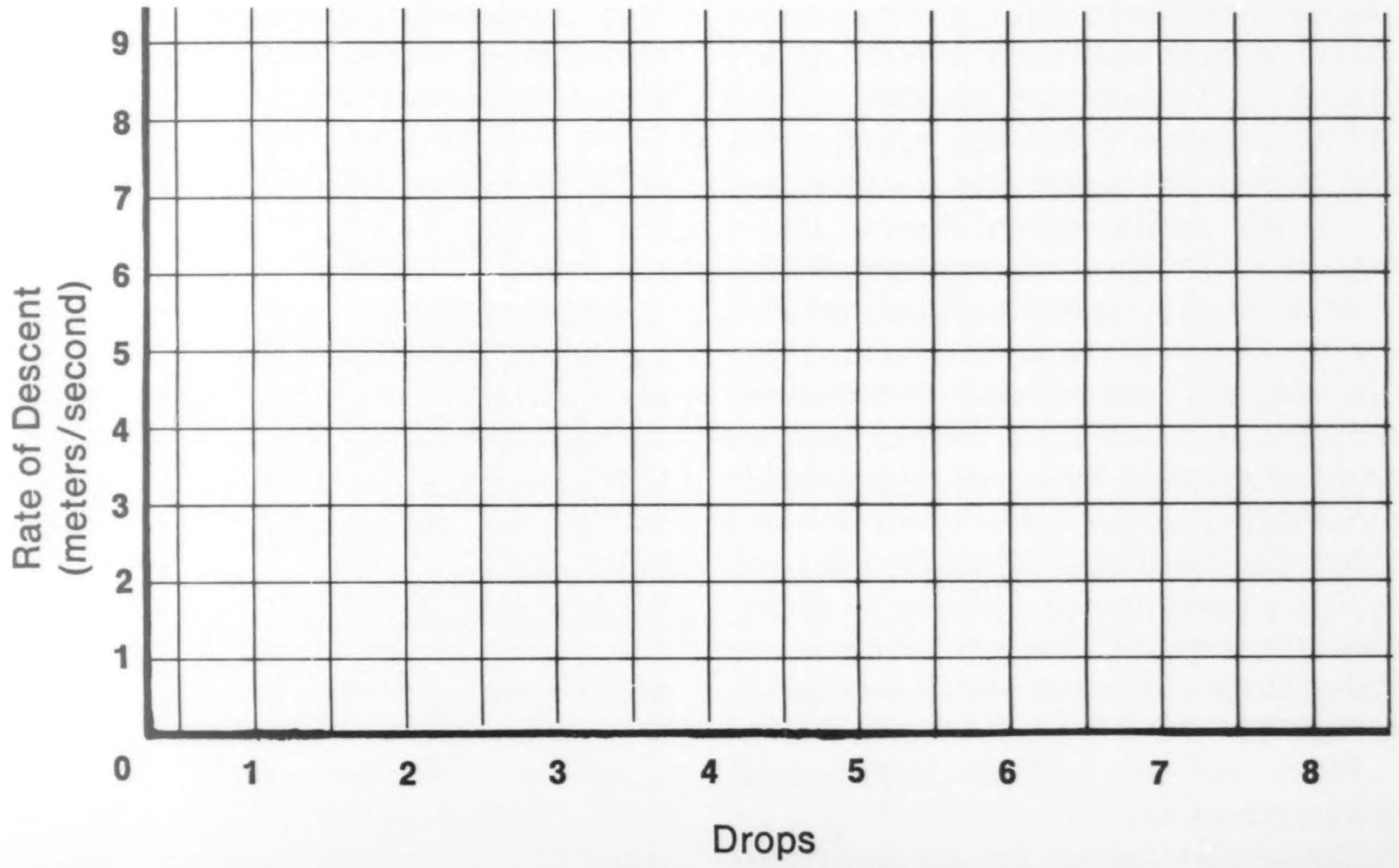
Tape a piece of nylon sewing thread or light string to each corner of the canopy. The length of the suspension lines should be at least 0.7 times the canopy diameter.

Hold the corners of the canopy together. Pull the free ends of the suspension lines together. Make sure the lines are the same length, then tie their free ends together with a single overhand knot.

Tie a washer, nut, or other small weight to the knot.



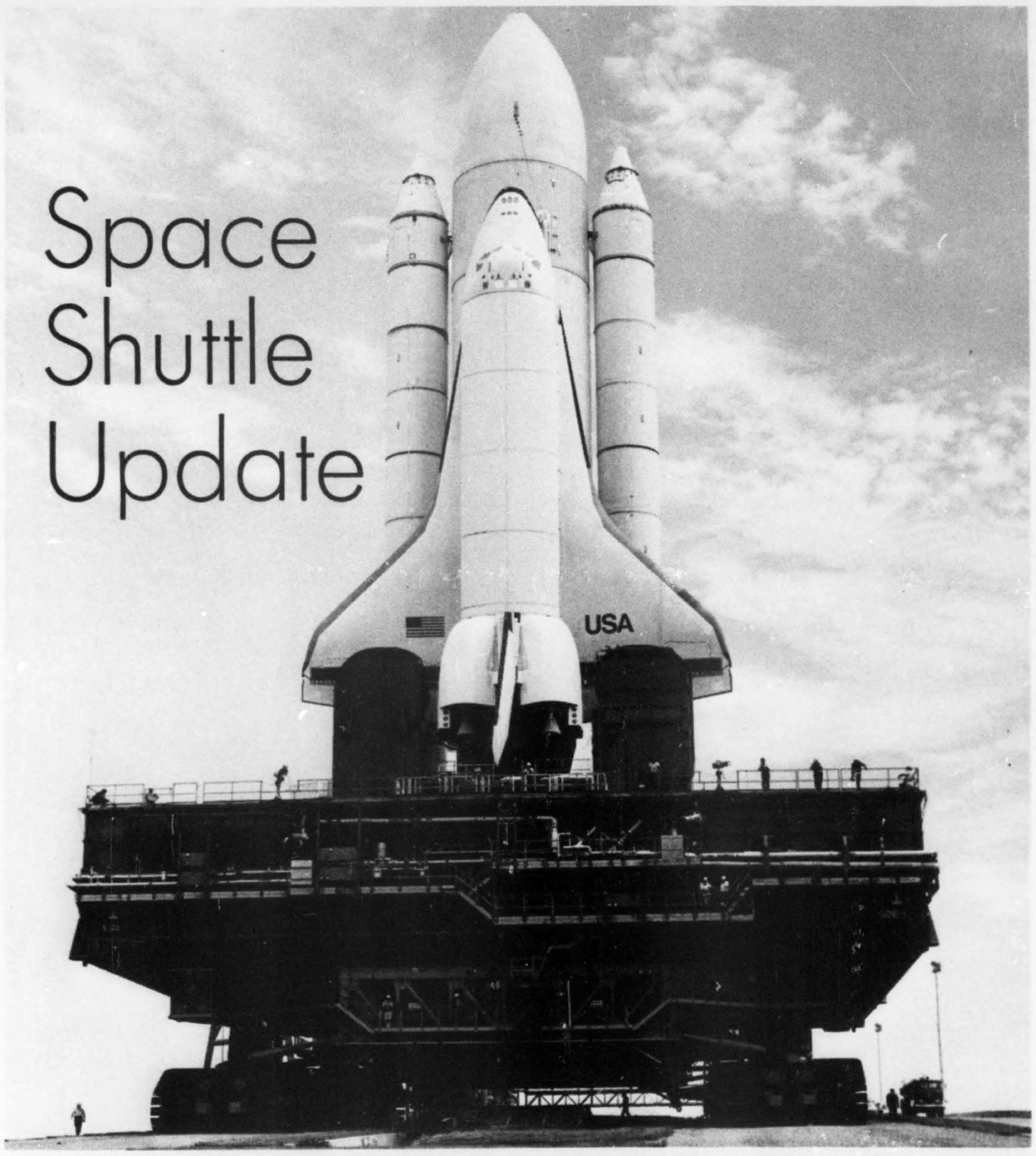
Descent Times



Rate of Descent

Space Shuttle Update

by Gregory P. Kennedy
Assistant Curator
Department of Space Science and Exploration, NASM



Space Shuttle Orbiter *Enterprise* (above) was mated with an External Tank and two Solid Rocket Boosters at the Kennedy Space Center in Florida for a facilities test in mid-1979. This test helped clear the way for its sister ship *Columbia* to be launched on its first mission into space, now scheduled for early 1981. Problems in several key areas of Shuttle development forced delays in the launch schedule for *Columbia*, the world's first reusable spacecraft. *Enterprise* served well as a testbed, but probably will not be used on space missions.

All payloads launched into space to date, whether they were manned spacecraft, scientific satellites, applications satellites, or planetary probes, have had one thing in common: they were boosted by expendable launch vehicles. The use of expendable launch vehicles has been one of the principle reasons for the high cost of space flight.

NASA is currently working on a reusable Space Shuttle Orbiter that will be able to deliver payloads to Earth orbit at a lower cost than the single-use boosters now in service. (See January-February, March-April, and May-June 1979 *Air & Space*.) The Space Shuttle Orbiter represents a new type of vehicle—one that must perform the functions of rocket, spacecraft, and aircraft during different phases of its flight.

Recently the Space Shuttle Orbiter program (now termed the Space Transportation System) has been plagued by a series of setbacks and delays, many of which can be attributed to the complex nature of this vehicle.

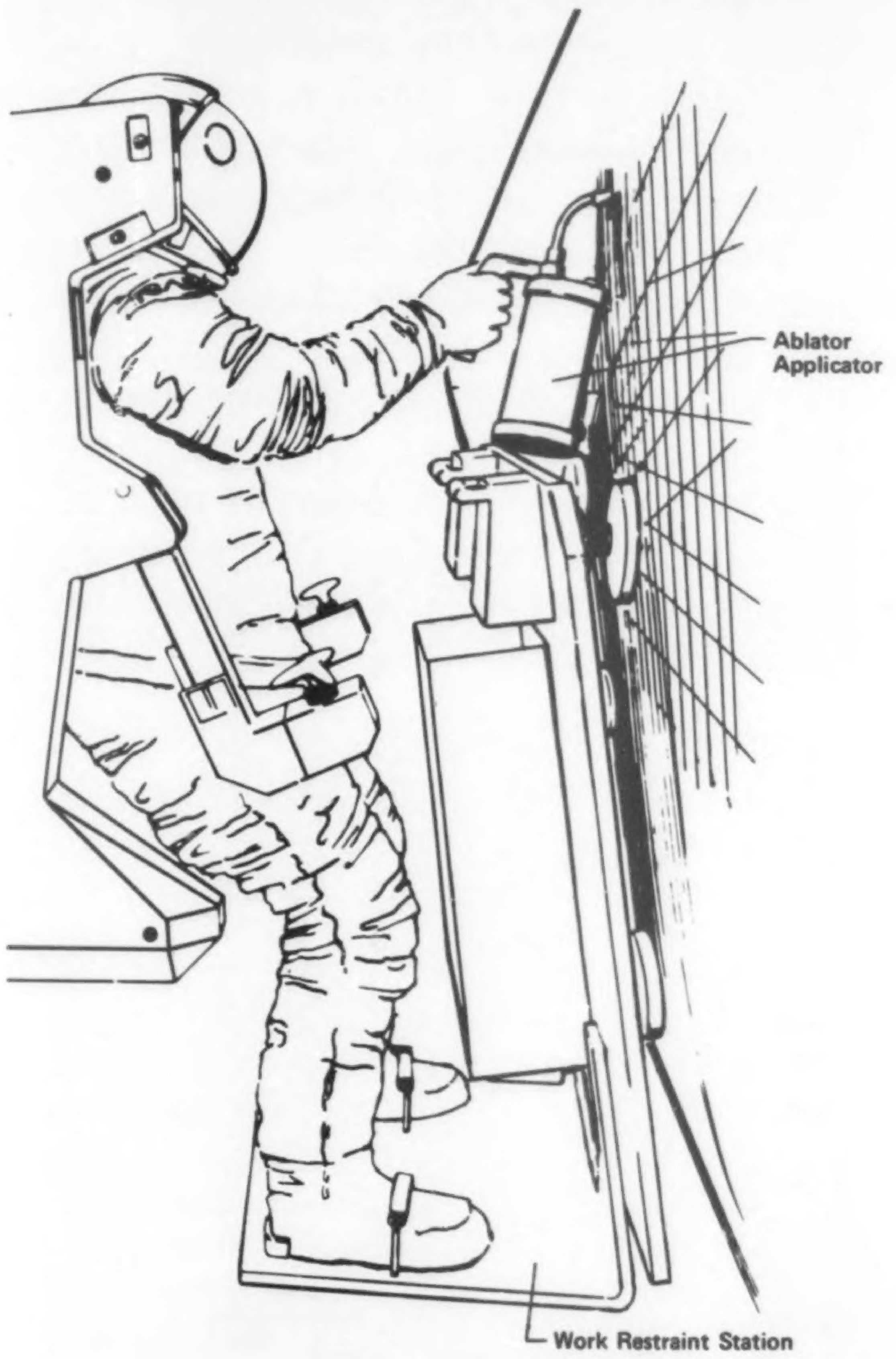
During ascent, the Shuttle is powered by two Solid Rocket Boosters (SRBs) and three Space Shuttle Main Engines (SSMEs). The SSMEs are mounted at the base of the Orbiter and burn liquid hydrogen and liquid oxygen, both of which are carried in the External Tank (ET). Each SSME generates a rated sea-level thrust of 1,668,080 newtons (375,000 pounds) and can be throttled from 50 percent to 109 percent of rated power.

In 1979, Shuttle engines being static-fired at the National Space Technology Laboratories in Mississippi experienced failures in the main fuel valve, turbine seals, and nozzle steerhorn, a section of hydrogen line near the base of the nozzle. The most serious problem was in the nozzle steerhorn, which failed because an incorrect welding wire (which was too soft) was mixed with the correct strength wire, resulting in a severely weakened weld joint. During a static firing on November 4, 1979, a weld on the steerhorn failed, resulting in an oxygen-rich combustion in the engine, which was extensively damaged. However, the various engine problems have been analyzed and modifications have been made to the SSME. On December 17, 1979, the first full-duration firing of a cluster of three SSMEs was made. Three-engine cluster firings in February and March were also successful. In April, Performance Flight Certification tests on the SSME were still in progress.

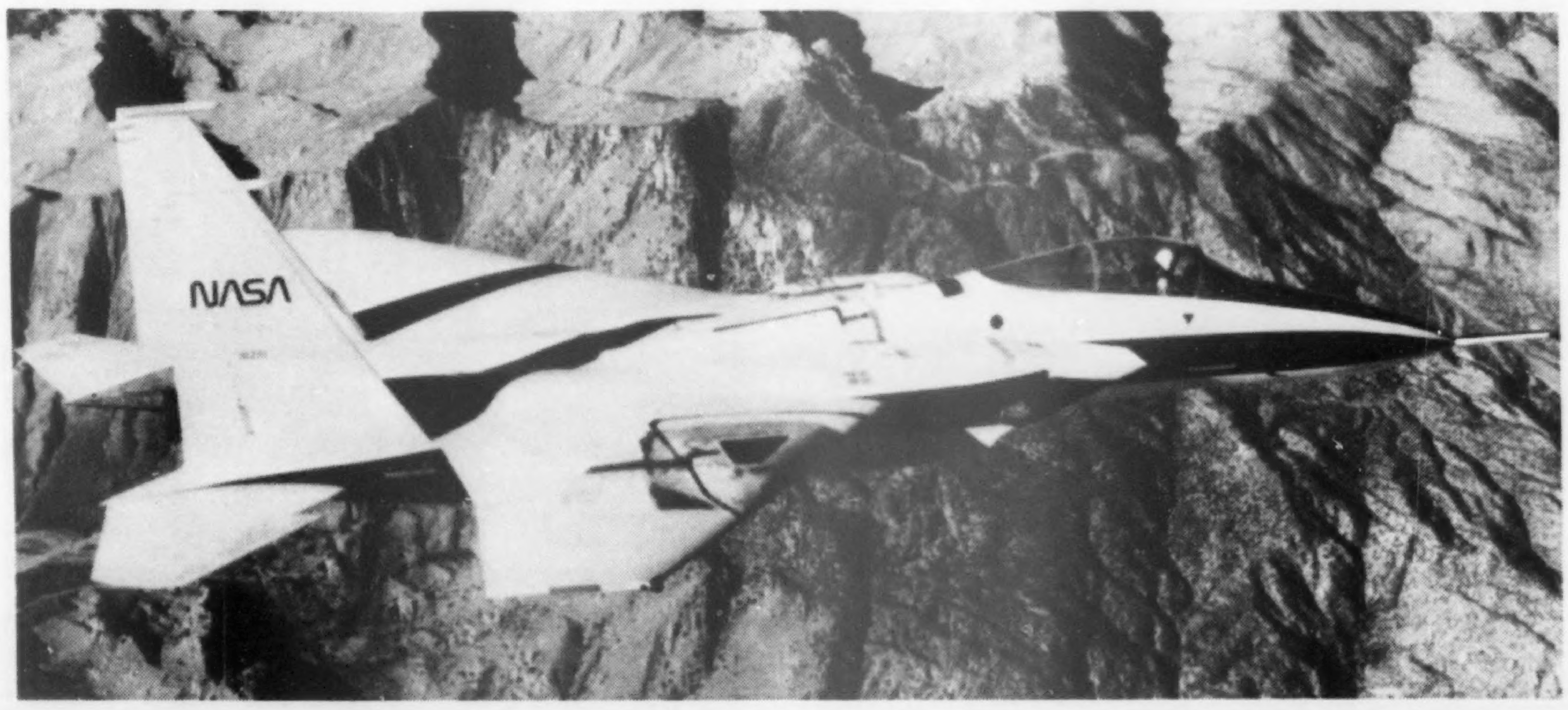
Unlike previous spacecraft that were protected from the searing heat of atmospheric reentry by ablative heat shields (that charred away as aerodynamic heating increased), the Shuttle Orbiter is covered with reusable surface insulation tiles made of coated silica fibers. Some 30,922 tiles cover about 70 percent of the Orbiter's exterior. The remaining 30 percent is covered by coated Nomex heat-resistant felt, reinforced carbon-carbon composites, metal, and glass.

Each of the tiles must be installed by hand; problems encountered during installation have caused the greatest delays to the Shuttle's schedule. During tests, it was found that many of the tiles failed when subjected to their ultimate design load (1.4 times maximum predicted flight load). The entire Thermal Protection System (TPS) of the Orbiter was reexamined, and all accessible critical tiles pull-tested to 1.25 times the highest predicted flight loads. Those that cannot be tested and those that fail the test will be removed and the tile strength and/or bonding system improved either by using a denser tile, by reconfiguring the tile "footprint" and thickness, or by improving the tile bonding technique.

Despite the problems that have been encountered, NASA officials have expressed optimism that astronauts John W. Young and Robert L. Crippen will pilot Orbiter 102 *Columbia* on its 54-hour shakedown flight in early 1981. The Solid Rocket Boosters and External Tank for the first flight are on hand at the Kennedy Space Center in Florida. Last January, NASA completed a 30-hour systems test in *Columbia*. This test, called the Orbiter Integrated Test (OIT), teamed astronauts in *Columbia* with flight controllers in Houston in a computer simulation of the Shuttle's countdown, launch, orbital flight, reentry, and landing. Successful completion of the OIT represented a major accomplishment in the process of preparing *Columbia* for flight because it verified compatibility of flight and ground equipment.



Above: A technician mounts ceramic-coated tiles on the Space Shuttle Orbiter *Columbia*. Almost 31,000 tiles make up the thermal protection system that will absorb the intense heat of air friction as the Shuttle reenters Earth's atmosphere after a mission in space. Each of the tiles must be installed by hand; problems encountered during installation have caused the greatest delays to the Shuttle's schedule. Below: Shuttle tiles have been flight-tested on F-15 research aircraft at NASA's Dryden Flight Research Center, Edwards, Calif. The tiles eventually will be submitted to almost 1.5 times the dynamic air pressure that the Shuttle will attain during launch. Left: Shuttle crews may use a special kit to repair possible tile damage in orbit. The kit would contain two kinds of repair material: blocks of precured ablative material to fill in large holes, and ablative paste to be used as an adhesive for the replacement blocks as well as a cure-in-place filler for areas smaller than tiles. The blocks are principally silicone rubber which will ablate from the heat of reentry. (Actual Orbiter tiles will not ablate during reentry.) The cure-in-place ablator is a paste-like substance with a silicon-rubber base to be applied with an applicator resembling a conventional caulking gun.



Student Activity

Any time a spacecraft reenters Earth's atmosphere, heat shields are necessary to protect the astronauts or instrument payload from the heat created by air friction on reentry. On the Orbiter, for example, surface temperatures during reentry may range from 1925 °K (3000 °F) on the nose and leading edges of the wings and tail, to 590 °K (600 °F) on the trailing surfaces. The systems used to protect spacecraft under such conditions utilize regenerative cooling, ablative cooling, and the "heat sink" concept. The following activities demonstrate the relative weights and heat protection capabilities of simple heat shields.

MATERIALS for each group of students:
flat-bottomed paper cup
water
wax candles
coat hangers

Activity One

Have each group of students weigh its paper cup, then hold it with a coat hanger over a lighted candle. Have the students measure and record the time it takes for the "spacecraft" to ignite. As soon as it begins to burn, immerse the cup in water. Be careful—and remember to have water beside the candles!

Activity Two

Have each group drip wax over the flat end of the cup until the cup bottom is covered. Let the wax-coated cup cool; weigh the whole system. Hold the cup over the lighted candle. Measure and record the time to ignition. Be careful—remember, hot wax burns!

Activity Three

Have each group cover the paper cup loosely with a sheet of aluminum foil. Weigh the system, then hold it over the lighted candle. Measure and record the time to ignition. Be careful—the hot foil can cause burns!

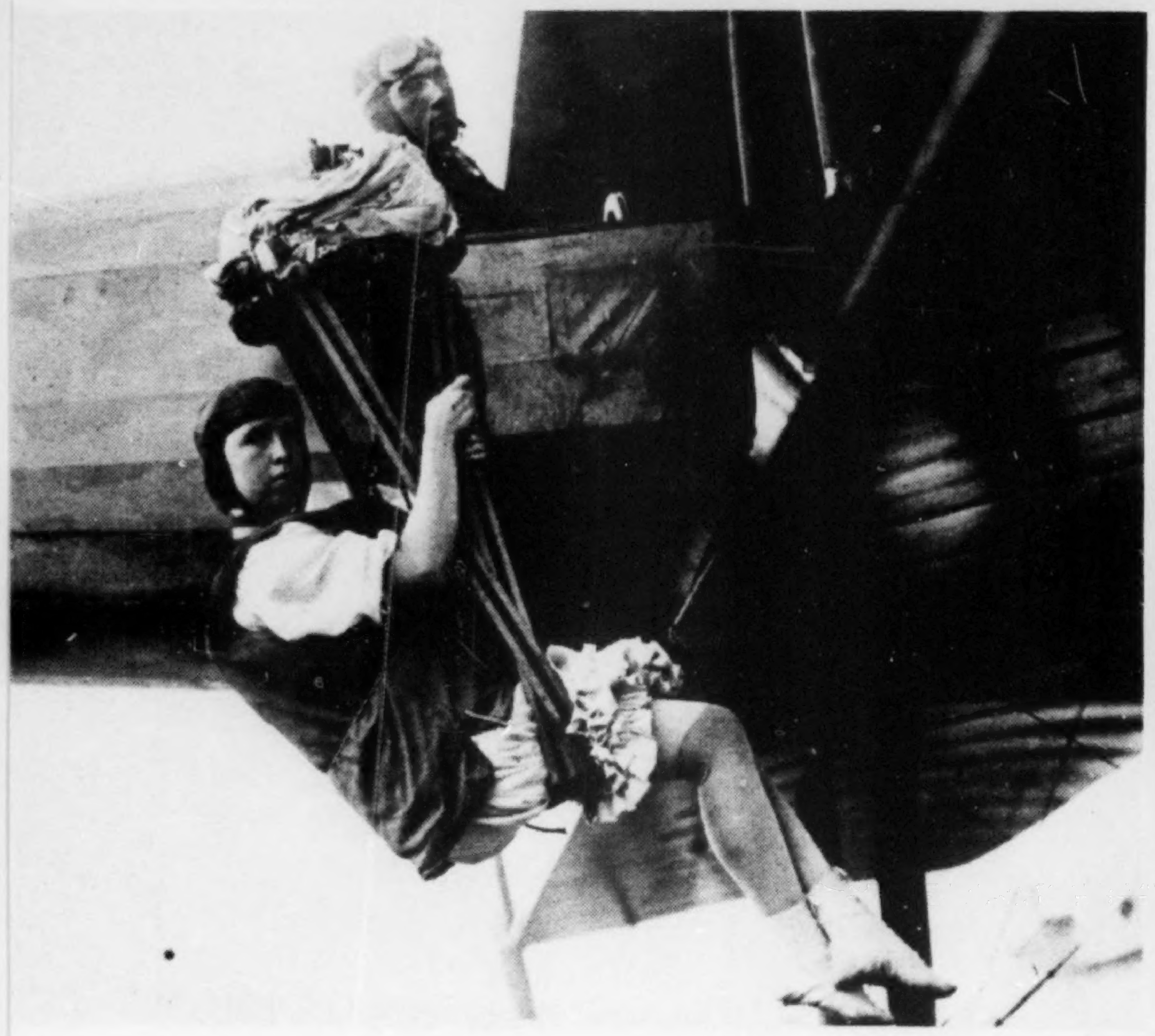
Activity Four

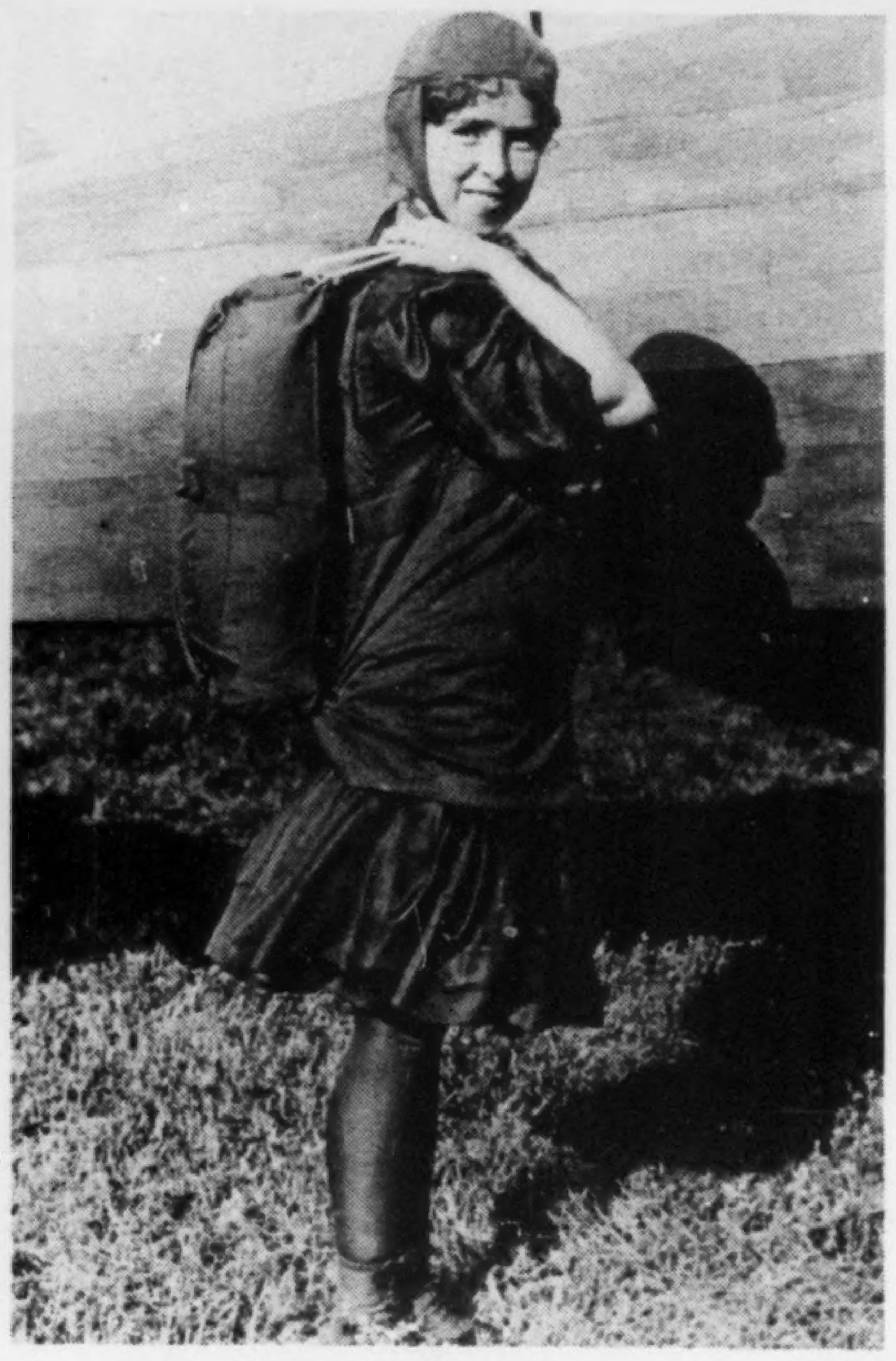
Have each group pour about 1 centimeter (3/8 inch) melted wax deep in the bottom of each paper cup. Weigh the system. After the wax cools, hold the cup over the lighted candle. Measure and record the time to ignition. Be careful—remember, hot wax burns.

Note: Hold the cups the same distance above the flame in each experiment.

Questions

1. Which system weighed the most?
2. Which system withstood the heat load the longest?





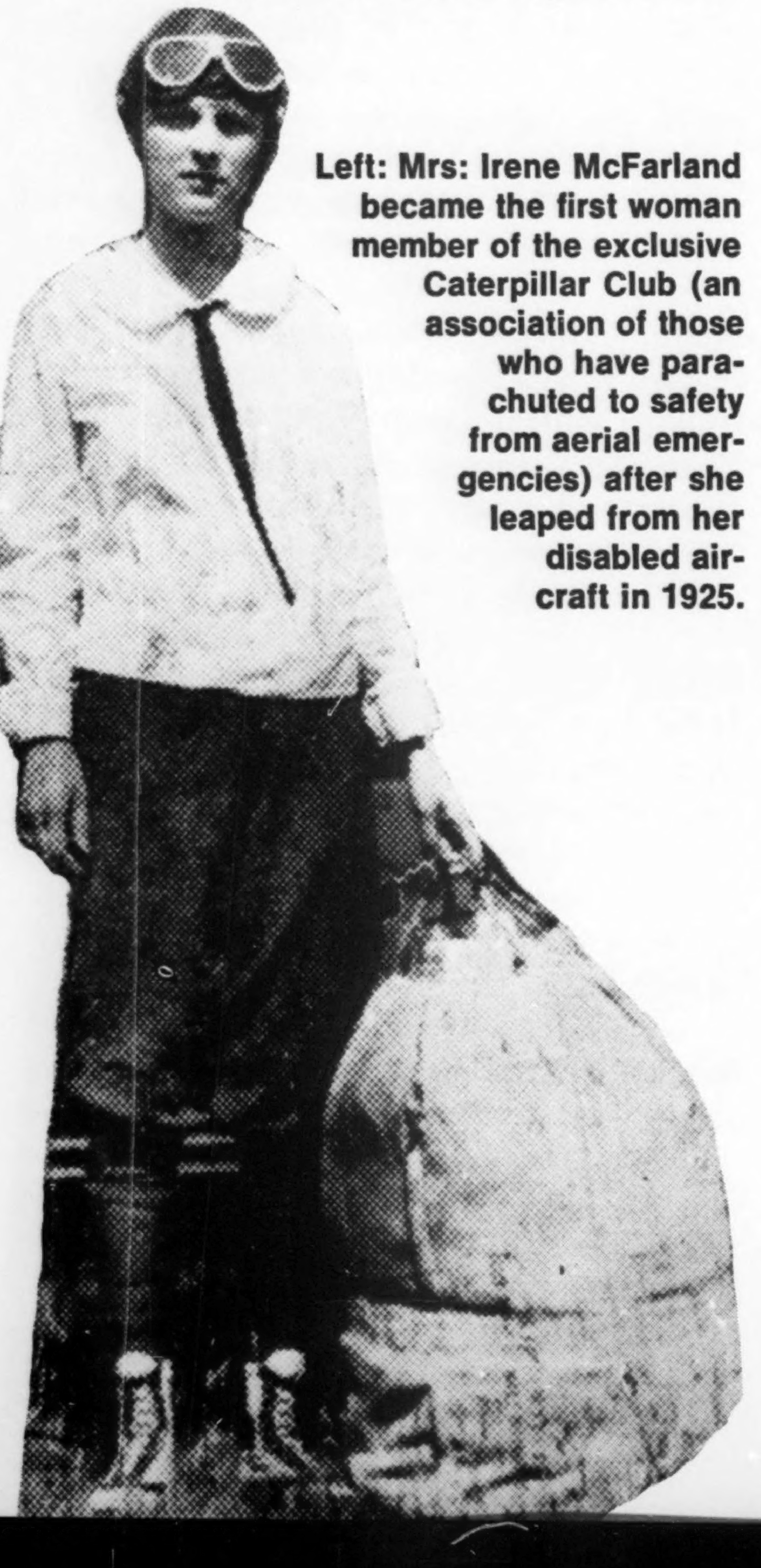
Far left: "Tiny" Broadwick, the first woman to parachute from an airplane, was also the first person to parachute from a hydroplane (floatplane). Here she is preparing to drop from a hydroplane (piloted by aviation pioneer Glenn L. Martin) into the cold waters of Lake Michigan in August 1913, as part of the Perry Victory Centennial Celebration in Chicago, Ill. Note her life preserver for the intentional water landing. Near left: "Tiny" also was the first person to demonstrate a parachute to U.S. Government officials, which she did in 1915, at San Diego, Calif. Her foster father and mentor, Charles Broadwick, in collaboration with Glenn Martin, built her relatively compact coat-type parachute.

Women Parachutists

by Claudia M. Oakes
Assistant Curator
Department of Aeronautics, NASM

The first parachute descent from an aircraft by a woman took place in 1799, when Jeanne-Geneviève Garnerin descended from a balloon flying over France. Madame Garnerin, also the first woman to fly solo in a balloon, was the wife of André-Jacques Garnerin who, in 1797, became the first person ever to descend from an aircraft by parachute (see page 4).

In 1815, Garnerin's niece, Elisa Garnerin, made the first of her many descents from balloons in Paris. By 1836, she had parachuted from balloons nearly 40 times.



Left: Mrs: Irene McFarland became the first woman member of the exclusive Caterpillar Club (an association of those who have parachuted to safety from aerial emergencies) after she leaped from her disabled aircraft in 1925.

Parachuting became a route to fame for women in the early days of aviation. The most famous of these daring parachutists—and the one who made the most significant contribution to the development and widespread use of parachutes—was a diminutive but spunky teenager from Granville County, N.C.

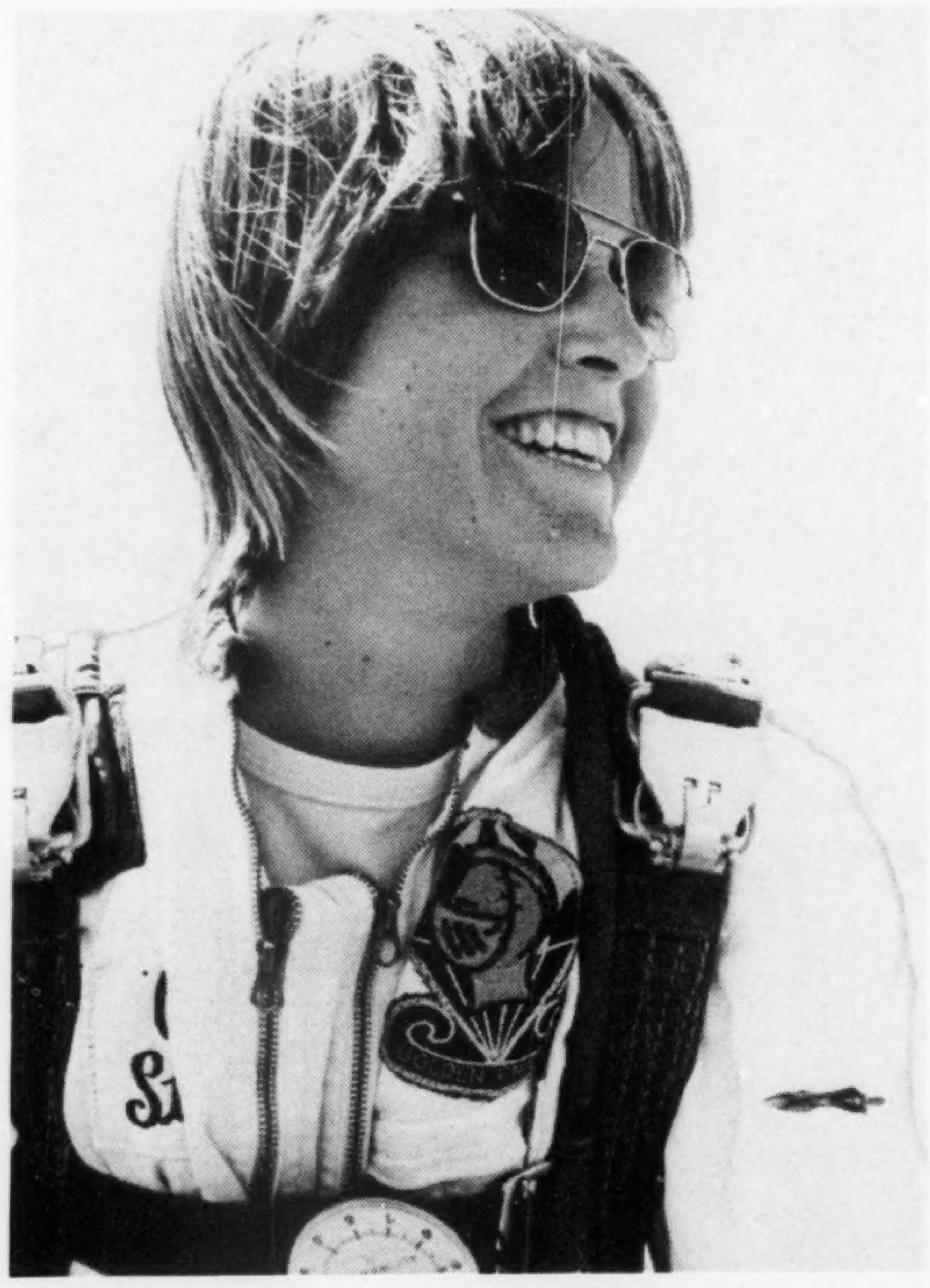
Her real name was Georgia Brown, but she was better known as "Tiny" Broadwick. In 1908, "Tiny" joined Charles Broadwick's exhibition group, taking his surname (as did all the group's members). "Tiny" agreed to make six parachute descents per week from a hot air balloon for $250, earning $25 for each additional descent. Sometimes she would perform with more than one parachute canopy, cutting them loose in succession as she descended. "Tiny" also jumped at night with flares extended about 60 centimeters (2 feet) from either side of her body.

On June 21, 1913, "Tiny" became the first woman to parachute from a heavier-than-air craft. Aviation pioneer Glenn L. Martin piloted the biplane that carried "Tiny" to a height of about 305 meters (1000 feet) above Griffith Park on the north side of Los Angeles, Calif. "Tiny" sat on a trap seat attached to the wing; when she was ready to drop, she released a lever that allowed her to fall. Her parachute opened perfectly, and she landed on her feet.

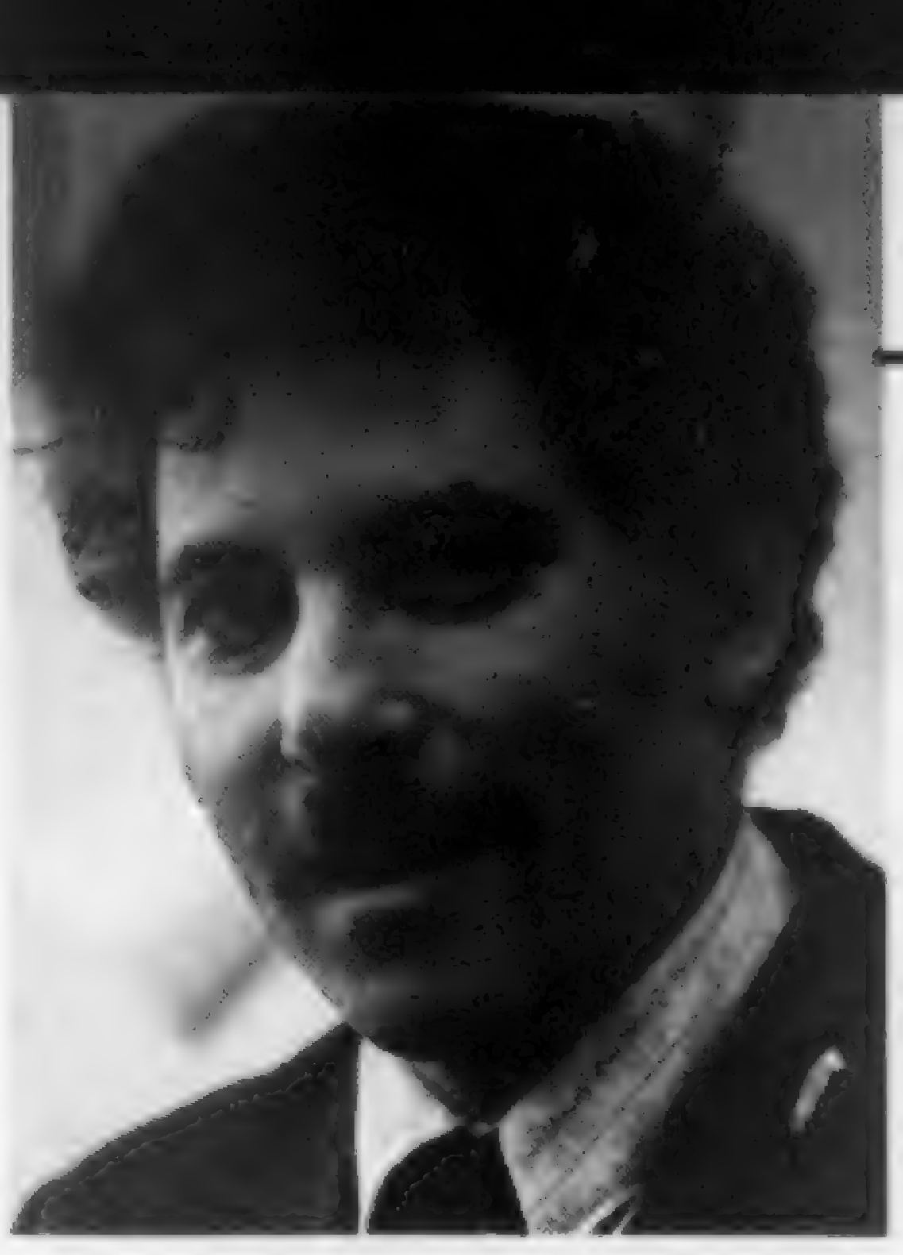
In 1915, "Tiny" made a jump at North Island, San Diego, Calif., becoming the first person to demonstrate a parachute to U.S. Government officials. She wore a "parachute coat" developed by Charles Broadwick in collaboration with Glenn Martin.

After making more than 600 descents, "Tiny" retired in 1922 because she felt the novelty had worn off for the public.

Today, the existence of women parachutists is still a novelty to some. However, women parachutists may be found jumpmastering paratroopers in the U.S. Army's airborne divisions, testing, selling, and demonstrating sport parachute equipment; working in parachute rigging lofts; and engineering new parachute designs. They also compete in regional, national, and international sport parachuting meets (in separate women's categories), set and break national and world records —continuing the legacy of pioneers like Jeanne-Geneviève and Elisa Garnerin and "Tiny" Broadwick.



Above: Sgt. Cheryl Stearns, the first of two women parachutists to join the Golden Knights (U.S. Army Parachute Team), holds 11 national and international parachuting titles, three women's individual world parachuting records, and is the current Women's Absolute World Parachuting Champion.



OUTREACH

by Kerry M. Joëls

Chief, Education Services Division

The metrication movement in education has produced considerable revenues for textbook companies, headaches for teachers, and very little metrication for the United States. There seem to be two basic approaches to the task of metrication: (1) the lengthy process of classroom education, and (2) the philosophy of quitting the English system "cold turkey" and adopting the metric system outright. Neither approach has worked in Canada, Great Britain, or the United States. It seems that few people are comfortable about changing the basic units of length, area, volume, and mass and weight that they use daily.

Common weights and measures, and their relationships to prices, are learned by habit. Homemakers know that one pound of beef makes four hamburgers and costs, say, $1.50. But how many homemakers know that 500 grams of beef will make the same number of hamburgers, and that $1.60 would be a fair price to pay for that amount?

Manufacturing products for world trade requires making them compatible with world standards of measurement. But the anxiety that results when a change in measurement systems is imposed seems overwhelming.

Perhaps we need to invent a third system, the "big M." In this third system of units we could find metric units that are rough equivalents of English measures, and call them by common English names. Children could still learn the metric system, while adults, for the price of an extra line of print on containers and packaging, would have an English equivalent.

For example, 500 grams equals about 1.1 pounds. If we call 1.1 pounds an M-pound, and charge 10 percent more for an M-pound than for an English pound, consumers would have hamburgers of almost the same size, and would not likely be able to tell the 10 percent price increase from normal inflation. Shoppers would comprehend one M-pound of beef at $1.65 much more easily than one kilogram of beef (or anything) at $3.30.

The concept could carry over to other weights and measures. The liter would become an M-quart; four liters, an M-gallon (110 percent of a gallon). The meter would become the M-yard, and 2½ centimeters would equal one Minch (40 Minches to the M-yard). Adults would speak of M-gallons, Minches, M-quarts, M-feet, M-yards, and M-pounds and would use measures only slightly larger than conventional English units.

Some problems would arise, of course. The kilometer would become the M-mile, but speedometers would be calibrated in kilometers per hour. Ninety M-miles per hour would equal 55 miles per hour.

We would have to make new rulers and scales, but manufacturers would merely produce metric goods, and check-out computers could tally prices and apply labels rather easily. People still could use the same familiar proportions of food in figuring portions and using recipes; estimate yard goods, carpeting, and building materials in familiar terms; and permit industry to metricize for competition in the world market.

This might be an off-beat suggestion. But how can we teach students if their parents will never let us get into the system?

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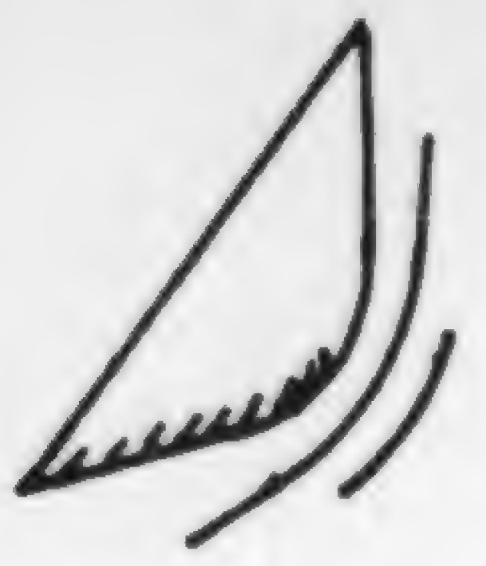
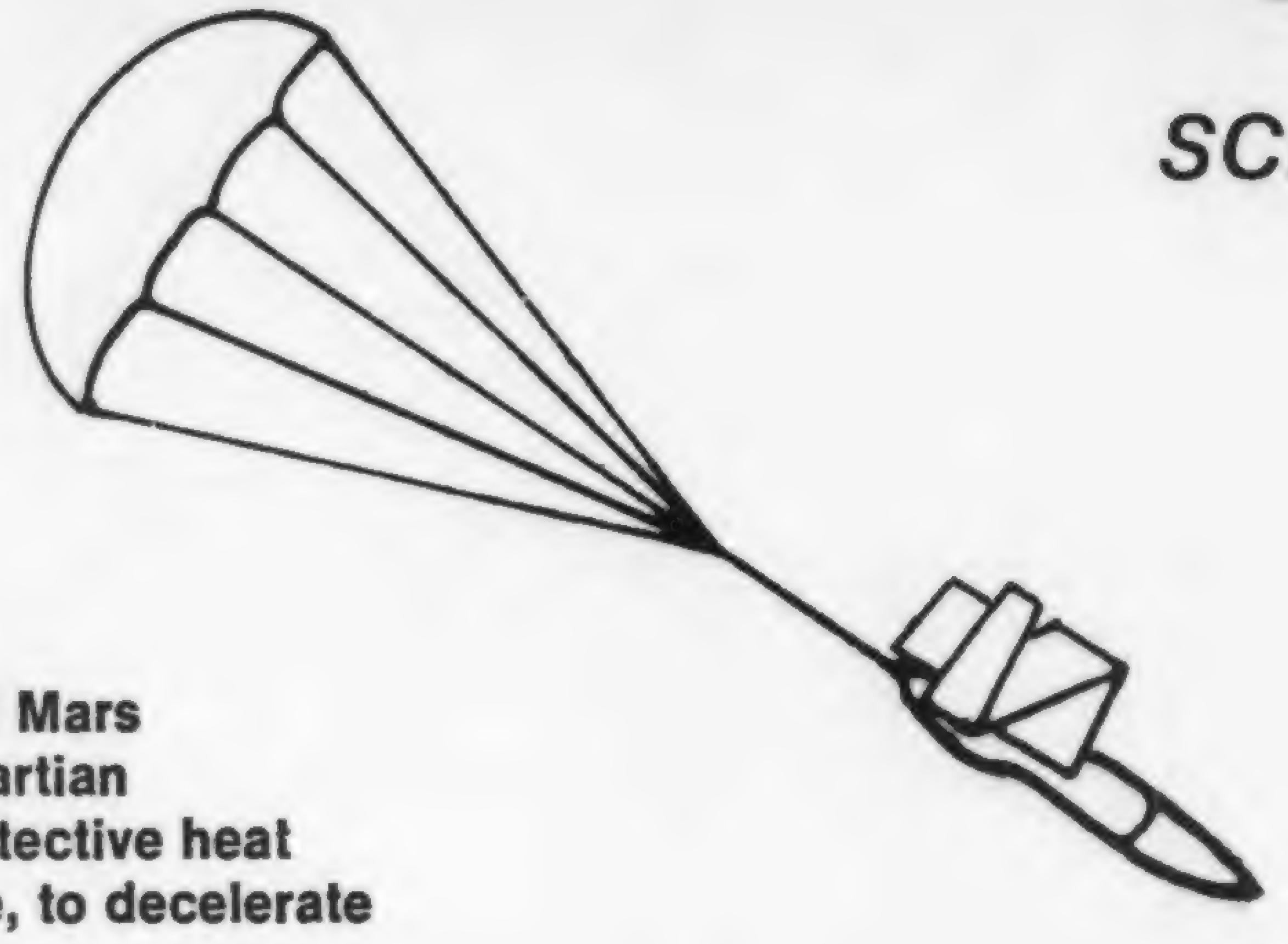
A Mars Airplane?

scientists consider an airplane design that's definitely out of this world





Folded into a compact package, a hypothetical Mars Plane enters the thin martian atmosphere using a protective heat shield, then a parachute, to decelerate

by Robert W. Wolfe
Geologist
Center for Earth and Planetary Studies, NASM

On July 20, 1976, Viking Lander 1 set down on Mars and, within minutes, began transmitting our first close-up view of the Red Planet's surface. Slowly, the alien scene filled television screens. Scientists were elated. But with its footpads anchored in the fine red martian dust, Viking's vision was limited. Scientists dreamed to see beyond the cratered horizon, a mere 4 kilometers (2½ miles) away.

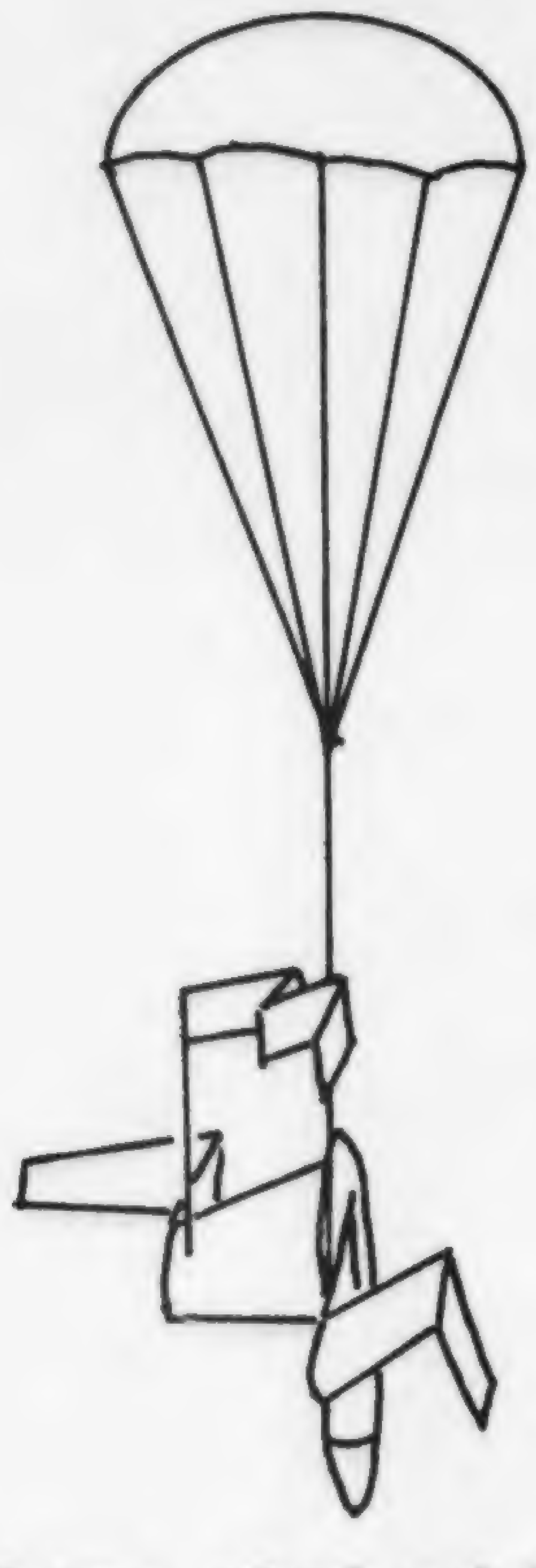
If only Viking had wings, could fly, explore! But what could fly in Mars' cold, thin atmosphere, having (at most) one percent of the density of Earth's? But wait—that's at sea level. Planes fly high where the air is thin. Let's see: at 33 kilometers (108,000 feet), Earth's air is as thin as the atmosphere near Mars' surface. We've flown that high in the North American X-15 and SR-71 Blackbird—but they're too big, too heavy to send to Mars. Oh well, it was just a dream.

Our mythical dreamer—perhaps enthralled by high-speed flight—probably never heard of Mini-Sniffer, a small, light-weight RPV (remotely piloted vehicle) developed by Dale Reed of NASA's Dryden Flight Research Center at Edwards, Calif. Designed to cruise for long periods and collect samples 27 kilometers (89,000 feet) high in the stratosphere, Mini-Sniffer has many attributes of an airplane that could fly on Mars: light weight, a relatively large payload capacity, the ability to sustain flight and maneuver in thin air, and a great range. Some of these capabilities actually would be enhanced in Mars' lesser gravity, about 38 percent that of Earth. The potential of Mini-Sniffer as a Mars airplane was first recognized by Jose Chirivella, an engineer at NASA's Jet Propulsion Laboratory in Pasadena, Calif., with whom Reed consulted on a matter related to Mini-Sniffer's hydrazine engine.

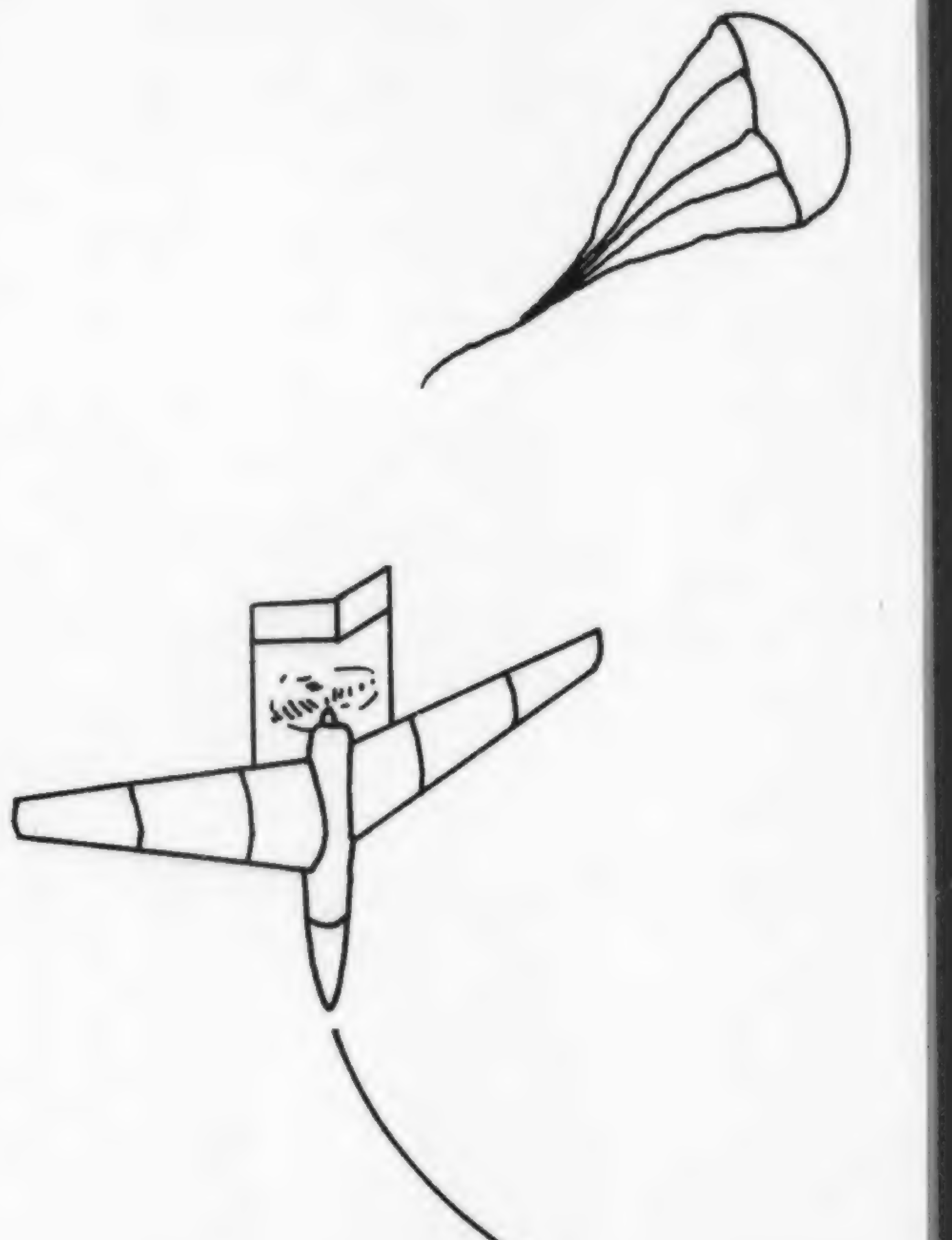
Engineers began thinking about the design of a Mars airplane based on the features of Mini-Sniffer, but optimized to fly in the martian atmosphere. They came up with a larger craft with a wingspan of about 20 meters (66 feet). To fit within a conventional spacecraft for transport to Mars, the airplane would need to be folded into a much smaller package. How could this be done? The airplane might use Astromasts—prestressed beams that can be collapsed and later deployed—for the fuselage and for the wing and tail spars, and a folding propeller. The 13-meter (43-foot) Astromasts that carry the magnetometers on the Voyager spacecraft were stored in a container less than ½ meter (1.6 feet) long.

Who would "pilot" the Mars airplane? The minimum time needed for the airplane to transmit a message or picture to Earth and to receive a reply is more than 8 minutes. Clearly, then, the airplane would need to pilot itself. The tasks of terrain avoidance and maintaining the proper "flight envelope" would be the responsibilities of sophisticated instruments and computers aboard the airplane. Acting on pictures and other information transmitted by the aircraft, controllers on Earth could periodically alter or update the flight path to restudy an area or to fly to a more interesting locale.

Today, there are no firm plans to send an airplane to Mars. But one day, perhaps, these extraterrestrial flights of fancy might become reality, greatly extending the horizons of our knowledge of the red planet.



Tail booms extend and lock in place; wings and tail unfold and lock; propeller unfolds and locks



Mars Plane releases from parachute; propeller starts to windmill

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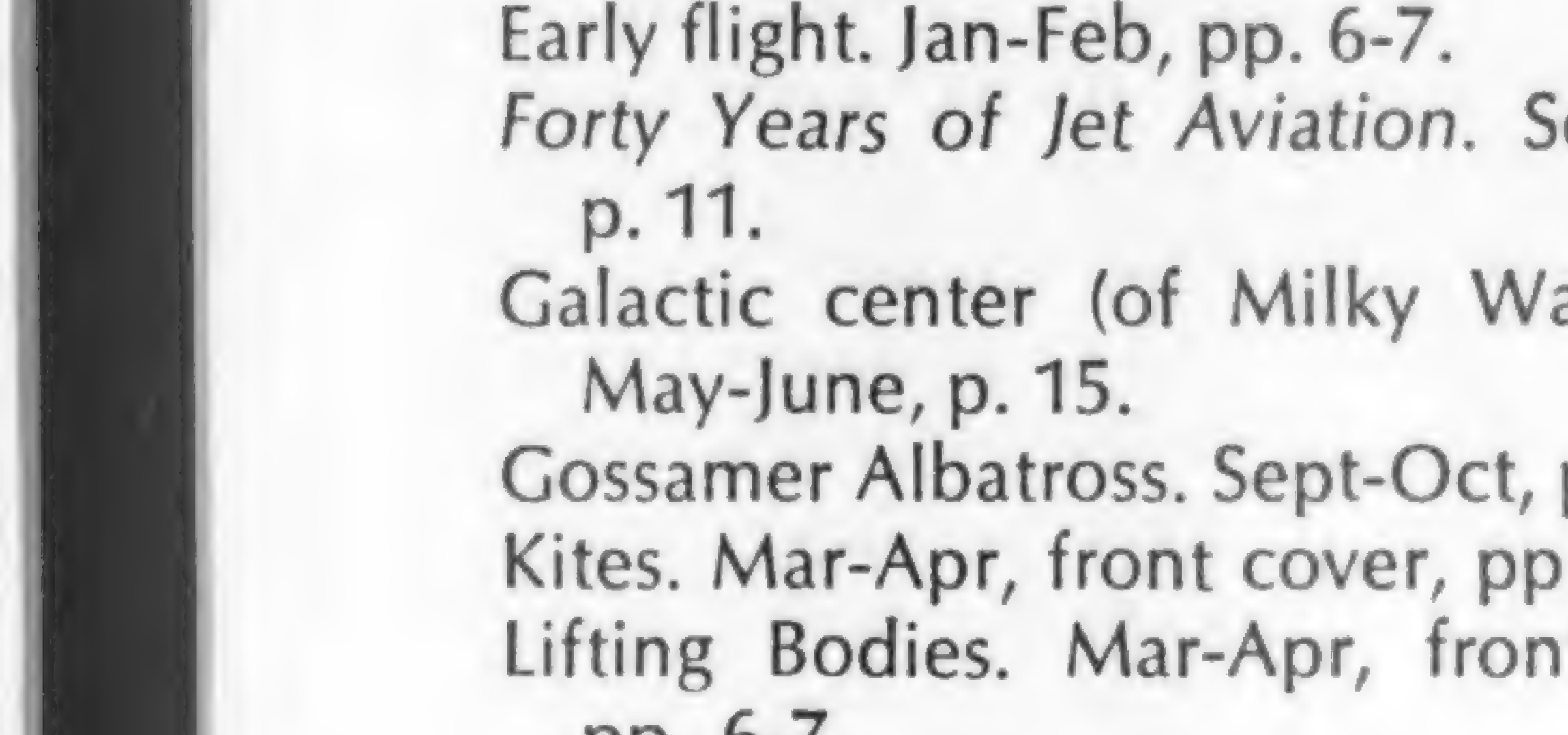
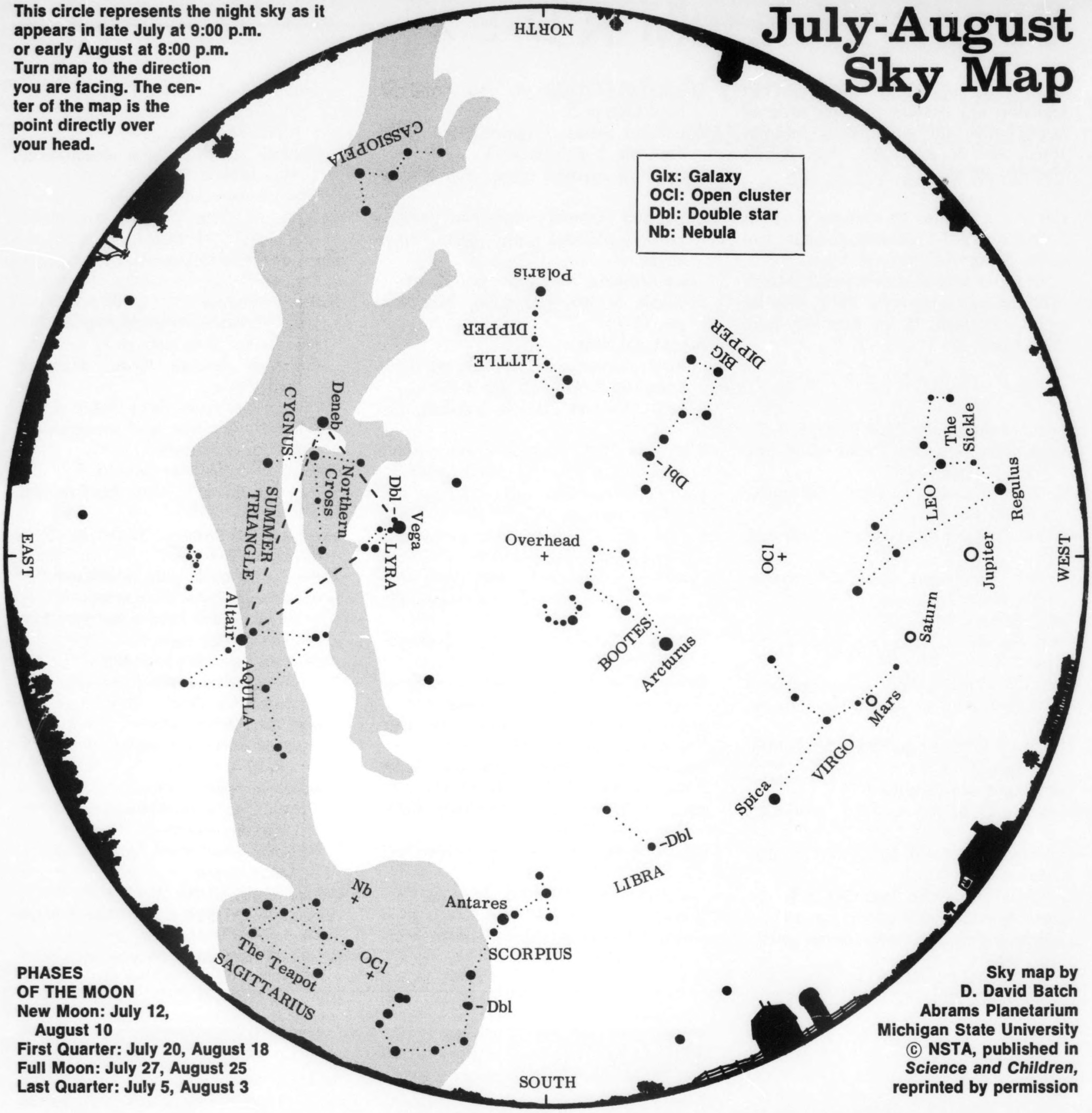
Mars Plane pulls out of dive and starts engine for cruise mission, an extended survey of the martian surface



Martians examining an alien airplane? No, just the ground crew preparing Mini-Sniffer for a high-altitude atmospheric sampling flight at NASA Dryden Flight Research Center, Edwards, Calif. Mini-Sniffer's hydrazine engine, developed for use in spacecraft, enables the Mini-Sniffer to fly at extreme altitudes and perform a variety of missions. An airplane concept using Mini-Sniffer technology is under consideration for future exploration of Mars.

July-August Sky Map

This circle represents the night sky as it appears in late July at 9:00 p.m. or early August at 8:00 p.m. Turn map to the direction you are facing. The center of the map is the point directly over your head.


NORTH
CASSIOPEIA
Glx: Galaxy
OCl: Open cluster
Dbl: Double star
Nb: Nebula
Polaris
LITTLE DIPPER
BIG DIPPER
Dbl
The Sickle
LEO
Regulus
Jupiter
WEST
OCl
Overhead
BOOTES
Arcturus
Saturn
Mars
VIRGO
Spica
-Dbl
LIBRA
Antares
SCORPIUS
-Dbl
SOUTH
Nb
OCl
The Teapot
SAGITTARIUS
EAST
CYGNUS
Deneb
Northern Cross
Dbl-
Vega
LYRA
SUMMER TRIANGLE
Altair
AQUILA

PHASES OF THE MOON
New Moon: July 12, August 10
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Sky map by
D. David Batch
Abrams Planetarium
Michigan State University
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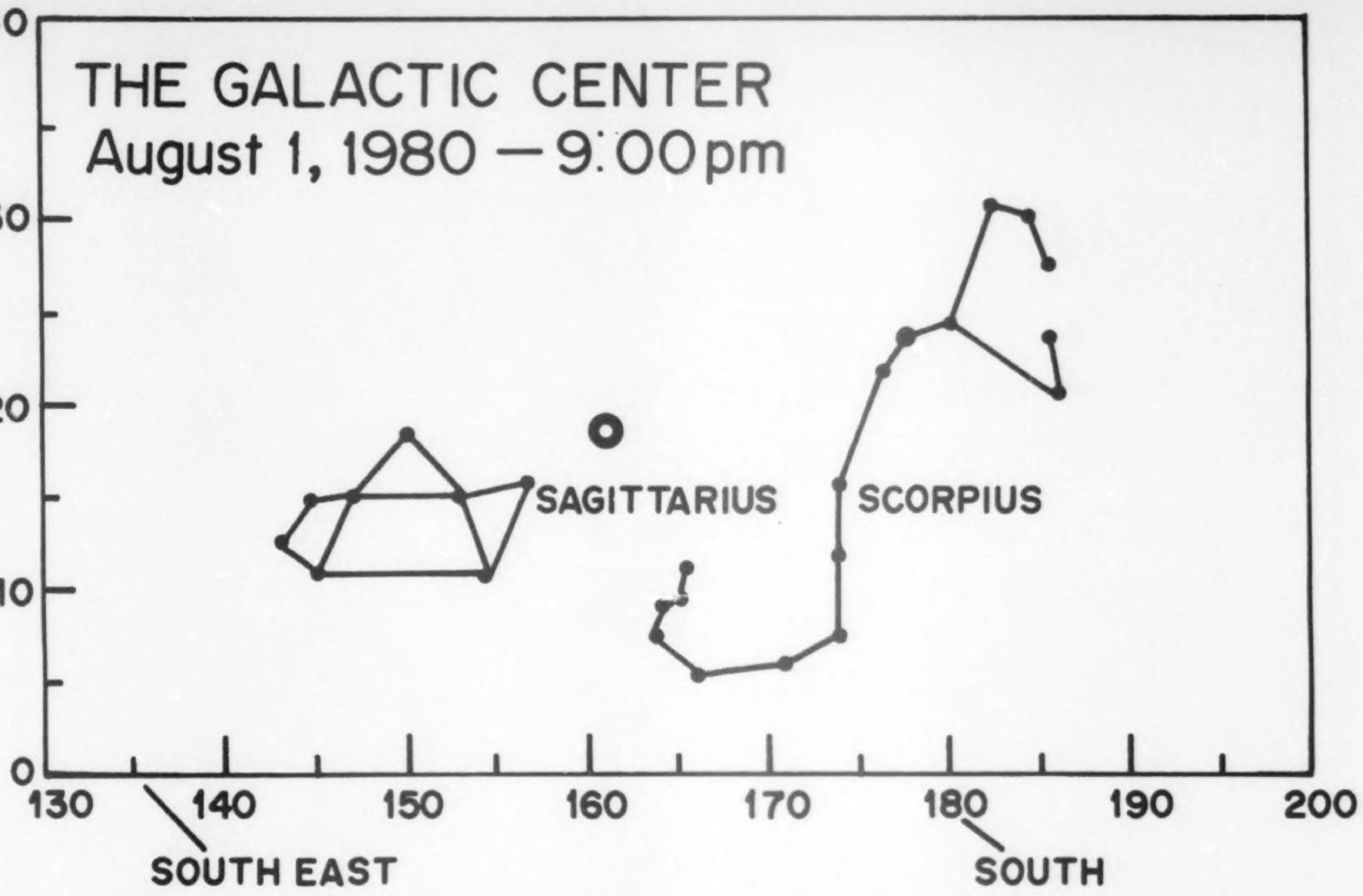
by T. H. Callen II
Production Specialist
Albert Einstein Spacearium, NASM

One of the perennial splendors of the summer sky is the Milky Way, part of the galaxy in which we live. It appears as a broad band of diffuse light because we are looking at this vast disk of stars edge on from the inside. Other summer stargazing treats, also part of the Milky Way, include the billowing star clouds of Scorpius and Sagittarius, now well placed for observation by unaided eyes or with binoculars and telescopes. Casual inspections of this region with binoculars or telescopes reveal several nebulae (glowing clouds of hydrogen gas and dust), areas actively producing new stars. Such surveys also bring to our attention open or galactic clusters, compact collections of several hundred stars. Such clusters of stars are believed to have formed at the same time from the same nebula.

Other star clusters, globular clusters, also are visible in the night sky, appearing like fuzzy white balls through binoculars or small telescopes. Globular clusters typically contain about 100,000 stars, and are the oldest objects known in galaxies. In 1918, American astronomer Harlow Shapley noted that these globular clusters tend to be concentrated in one half of the sky, one third of them in the direction of the constellation Sagittarius. Having determined their distances from the Earth, Shapley correctly theorized that the center of our galaxy lay in that direction. Study of other spiral galaxies showed that their globular clusters formed a halo around their galaxy's nucleus. We know today that our star, the Sun, is about 33,000 light-years (3.12 X 10^{17} kilometers, or 1.94 X 10^{17} miles) from the center of the Milky Way Galaxy.

This year's annual Perseid meteor shower, peaking on August 11, should be spectacular, as the new Moon will insure dark skies. (To observe the shower, it is best to find a site away from city lights.) Weather permitting, up to 50 meteors per hour may be visible to a single observer as they streak into the Earth's upper atmosphere at speeds of about 60 kilometers (37 miles) per *second* and burn up. While watching this event, try to keep in mind that the particles causing this celestial fireworks display are only about the size of sand grains!



The Galactic Center

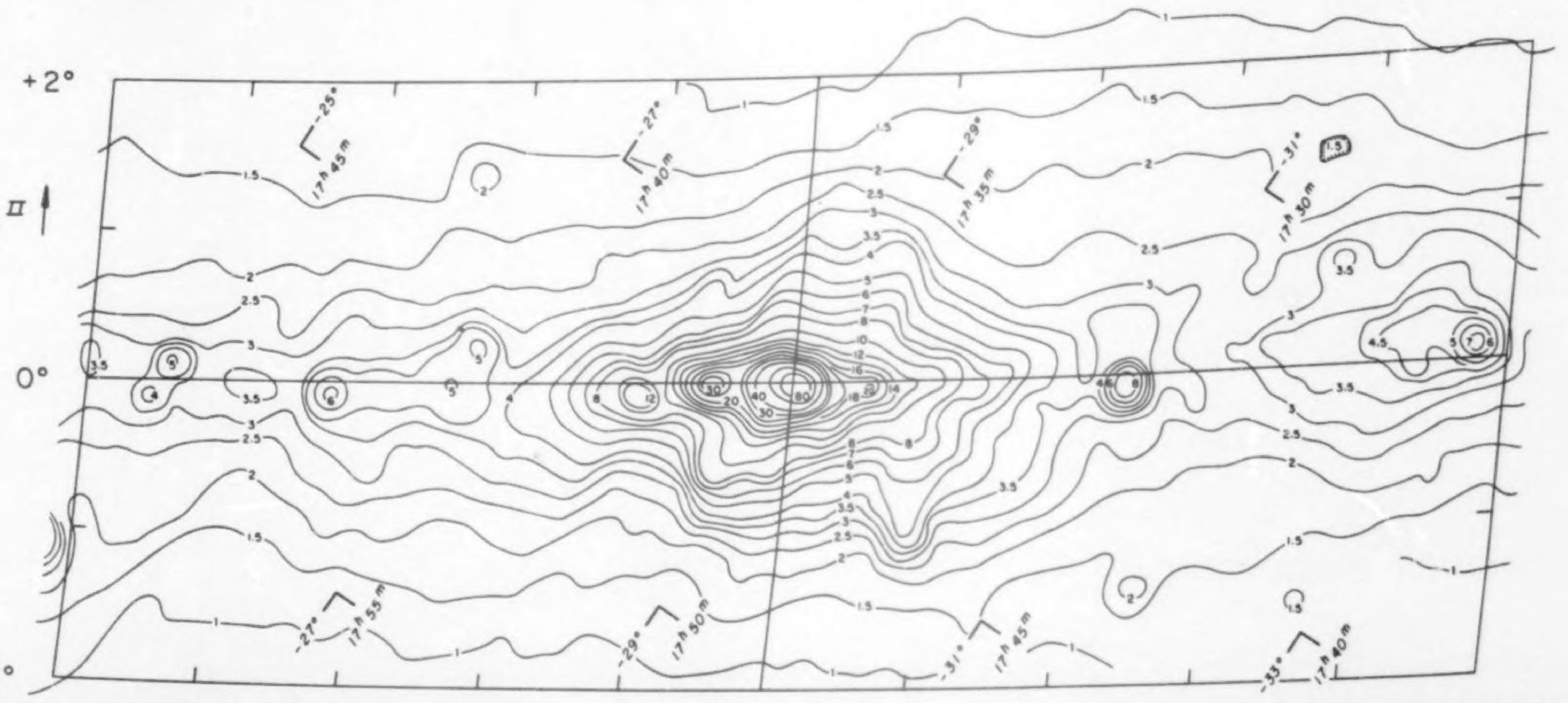
by T. H. Callen II
Production Specialist
Albert Einstein Spacearium, NASM

The diagram above shows the location of the center of our Milky Way Galaxy, relative to the constellations Sagittarius and Scorpius, at about 9:00 p.m. on August 1, 1980. We might expect the region of the sky near the galactic center to be quite bright—other spiral galaxies show bright, active regions in their nuclei caused by an, as yet, unexplained process. However, we receive only about one ten-billionth of the light we would expect to see from the center of our Galaxy. While the distribution of interstellar matter in our Galaxy is essentially thin, there is enough dust and gas in the space between us and the galactic center—33,000 light-years distant—to scatter or absorb most of the light from this region. The scale along the bottom of the diagram shows azimuth, or compass heading, in degrees, while the scale along the diagram's side shows altitude, or height above the horizon, in degrees.

Compare the diagram above with the radio view of the galactic center (below). Each contour on the radio map represents an interval of radio signal intensity at a wavelength of 11 centimeters (4.3 inches, or 2.7 X 10^9 hertz). The galactic center lies in the direction from which the most intense radio energy is being emitted. The map was plotted by computers linked to the 42.7-meter (140-foot) radio telescope of the National Radio Astronomy Observatory (NRAO), Green Bank, W. Va.

To orient the radio map to the visible sky diagram, rotate the map clockwise until the arrow just below it points straight down.

This map shows two coordinate systems. The traditional celestial coordinate system used by most astronomers measures Right Ascension (R.A.) in hours and minutes (from 0 to 23 hours 59 minutes) from an arbitrary point in the sky, and Declination (Dec.) in degrees and minutes (from 0° to ±90°) above or below the plane of the Earth's equator. The galactic coordinate system uses l^{II} for longitude in degrees (from 0° to 360°) around the plane, or equator, of the Milky Way Galaxy, and b^{II} for galactic latitude in degrees (from 0° to ±90°) above or below this plane. The starting point for this system is the galactic center. In the galactic coordinate system, the position of the galactic center is $l^{II} = 0°$, and $b^{II} = 0°$; in the celestial coordinate system, R.A. 17 hours 42.2 minutes, Dec. —28° 55′.



Free Presentations on Aviation and Space Available

NASM has trained nine educators to give presentations in their communities on the history and significance of aviation and space.

The educators participated in an experimental Regional Resource Person Training Session held in July 1979 at NASM in Washington, DC. The program, new last year, included an intensive course in the history of aviation and space and a review of teaching methods. The educators have returned to their communities where they will teach other instructors the history of aeronautics and astronautics and ways to integrate these subjects into the school curriculum.

These Regional Resource Persons will make free presentations to teachers, students, and to the general public:

Darrell E. Asbury, Morgantown High School, Morgantown, W VA;
G. Courtney Chapman, Ohio State University, Columbus, Ohio;
Walter Dinteman, Camden County College, Blackwood, NJ;
Virginia Ellett, Mathematics and Science Center, Richmond, VA;
Dr. Fred Hofkin, School District of Philadelphia, Philadelphia, PA;
Sister Jean Margaret Kaindl, Mother Guerin High School, River Grove, IL;
Richard Rooney, New Castle County School District, Wilmington, DE;
Lockhard Smith, Jr., Wentworth Institute, Boston, MA; and
Sherman Taffel, Lake Clifton Senior High School, Baltimore, MD.

For more information on presentations in your community, contact the Regional Resource Person in your area. For further information on the Regional Resource Person Program, contact Janet Wolfe, Education Services Division, National Air and Space Museum, Washington, DC 20560.

ILLUSTRATION CREDITS

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THINK ALONG WITH THE AEROSPACE ENGINEERS

about how to land a spacecraft on Mars

by Howard T. Wright
Director for Projects
NASA Langley Research Center

Planning the Viking missions—to search for life on Mars—raised many technical problems that had to be solved for the first time. For example, what would be the best way of slowing the two Viking Landers for soft landings on Mars?

Unlike Earth's Moon, Mars has an atmosphere, albeit a thin one. Viking engineers decided that the Landers should enter the thin martian atmosphere in a manner similar to that of manned spacecraft reentering the Earth's atmosphere.

Each Lander would enter the upper martian atmosphere at 16,000 kilometers (10,000) miles) per hour; the craft's blunt ablative heat shield would dissipate the tremendous heat of aerodynamic friction. (Allowing a thin layer of material on a surface to char away as atmospheric heat builds up is called *ablation*. Gases generated by the ablative process help insulate the spacecraft from further heating.)

After slowing considerably, the spacecraft would deploy a parachute at about 5700 meters (18,700) feet) above the surface. At 1400 meters (4600 feet), the Lander would jettison the parachute canopy; three rocket thrusters would brake the Lander during the last segment of its descent.

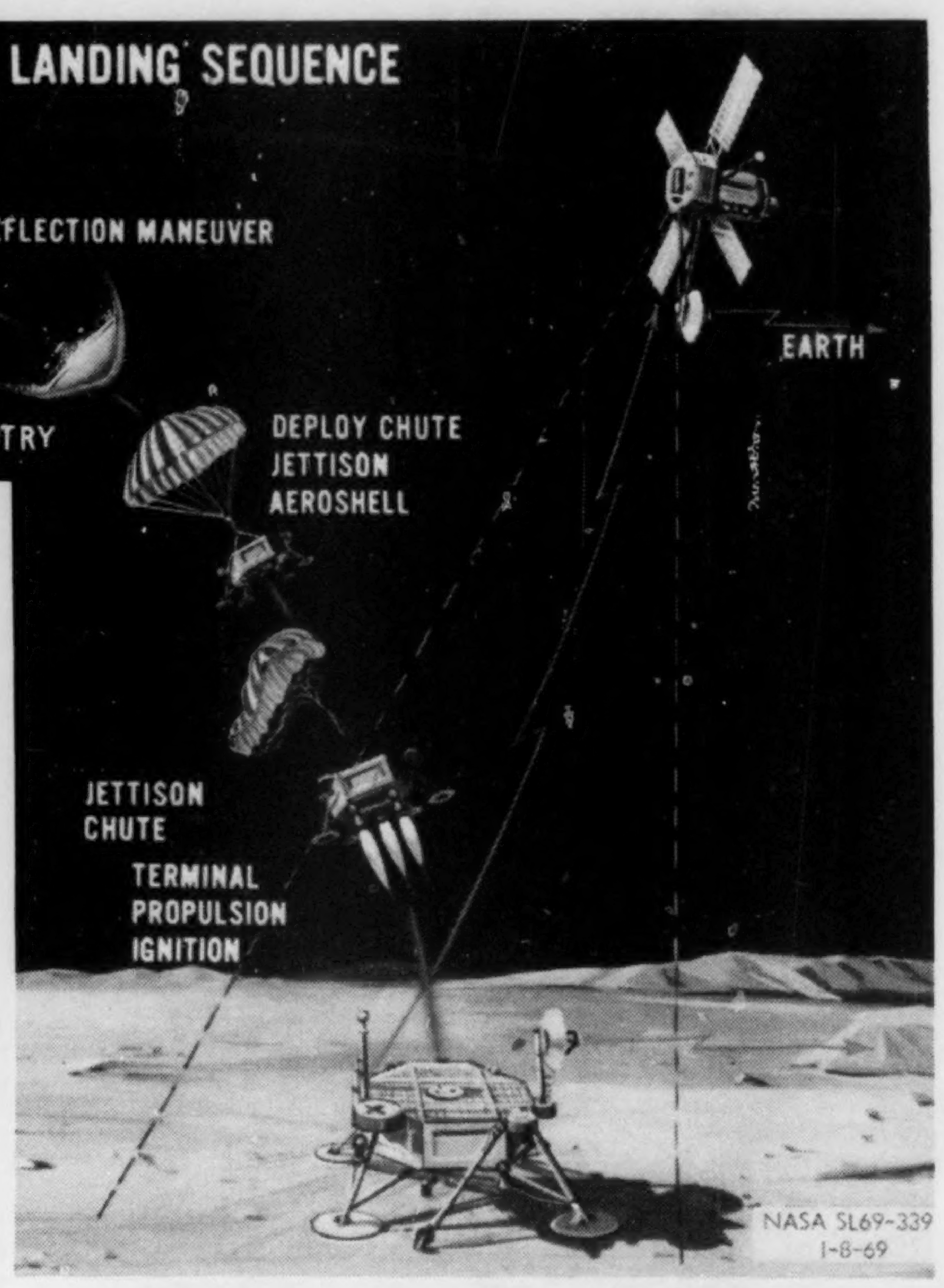
Viking engineers, seeking simplicity, ease of construction, and high reliability, chose a disc-gap-band design for the Viking Lander parachute canopy. The central disc portion of the canopy would provide high aerodynamic drag; the gap-band, excellent deployment characteristics and canopy stability.

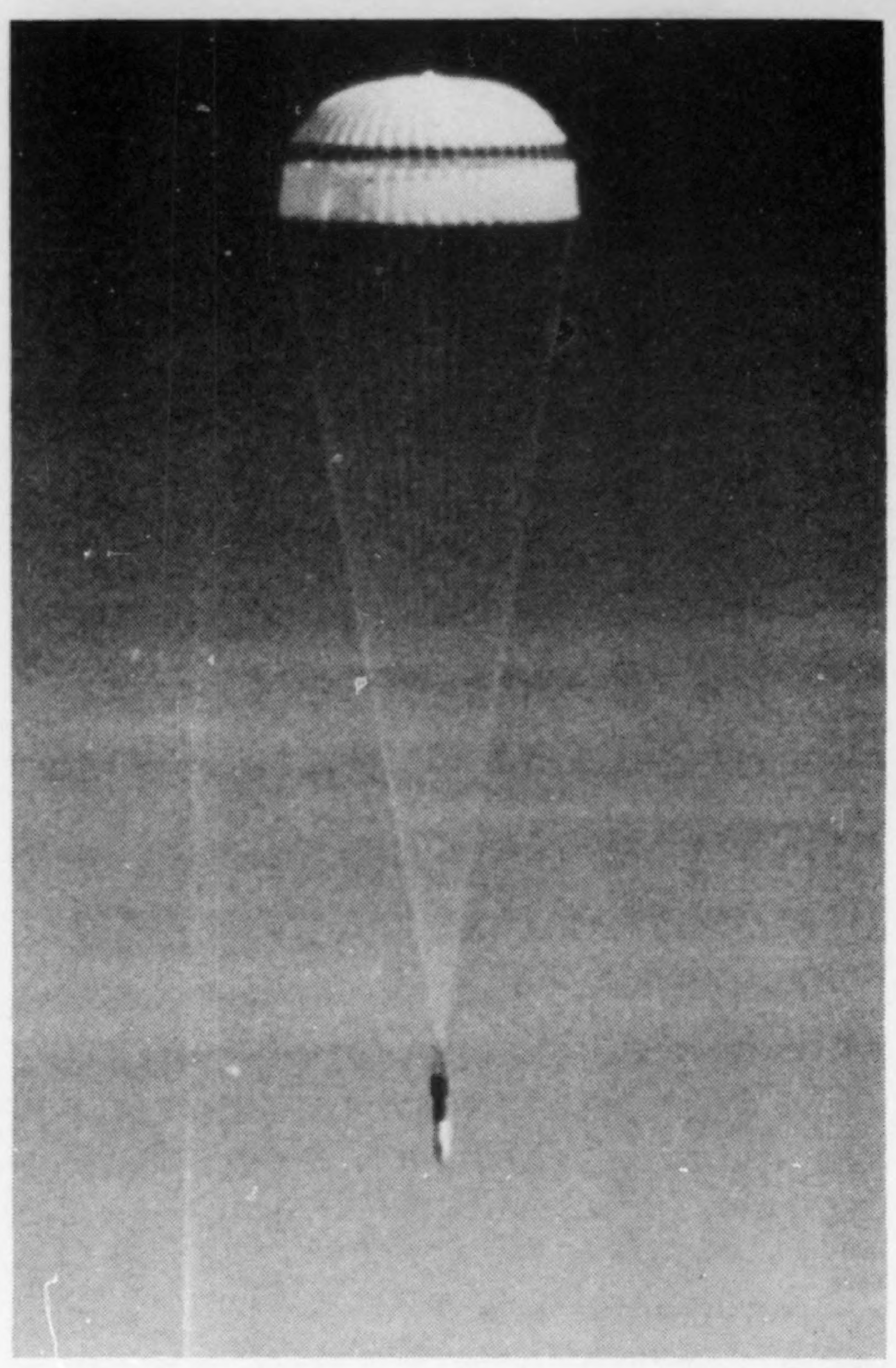
The parachute system was 16 meters (53 feet) in diameter, 30 meters (98 feet) long, and weighed 50 kilograms (110 pounds), including the mortar deployment system. It was designed to be deployed at velocities above Mach 2 (2510 kilometers, or 1560 miles, per hour) and to decelerate a 1134-kilogram (2500-pound) payload to 97 kilometers (60 miles) per hour within one minute. The parachute had to withstand biological sterilization: the entire parachute system was "cooked" at 135 °C (275 °F) for 40 hours before beng placed in the spacecraft. The canopy was packed to a density of about 705 kilograms/meter^3 (44 pounds/foot^3)—about the density of maple wood!

After being "cooked," packed in its 56- by 38-centimeter (22- by 15-inch) canister for more than 2½ years, and frozen in deep space for a year, this 17-kilogram (38-pound) piece of cloth was expected to perform flawlessly and withstand a 7260-kilogram (16,000-pound) opening shock load.

It did. On July 20, 1976, Viking Lander One touched down successfully on the Chryse Planitia (Plains of Gold) on Mars. Lander Two landed on Utopia Planitia on September 3, 1976. Since 1976 the Landers have continued to gather a wealth of information that has forever changed mankind's understanding of the red planet.

A Viking Lander Proof Test Capsule, a real Viking spacecraft used in ground tests before and during the flights, is on display in NASM's Milestones of Flight gallery.





In 1972, NASA drop-tested the Viking parachute with a 907-kilogram (2000-pound) weight (left) from a B-57 aircraft 15.2 kilometers (50,000 feet) high. To simulate parachute deployment in Mars' thin atmosphere, NASA flew the world's four largest successful balloons to 36.3 kilometers (119,000 feet), from which rockets flew the parachutes to Mach 2 openings at 42.7 kilometers (140,000 feet).

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